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Gas Turbines.

The success which has been achieved in developing the steam turbine has given a fresh impetus to the investigation of the problem of devising a practical prime mover of similar type, with hot air or other gases as the driving force. The problem is not a new one; it had long been present to the minds of engineers, but had been put aside for the moment in favour of others, which offered greater chance of commercial success, even if their solution should not lead to an engine of so high an efficiency as may be anticipated in the case of the gas turbine. To-day, however, the situation is somewhat altered, as the new experience gained from the steam turbine has placed us in a better position to cope with the difficulties which face us in attacking the old problem; and he would be a bold man who would say that these difficulties are too great to be overcome.

The first step of progress is made when we have separated out the different obstacles in the way, and have realised the precise nature of each and the direction from which it should be attacked; and that we are now in this position will be gathered from a study of the interesting paper communicated by Mr. R. M. Neilson to the Institution of Mechanical Engineers, and reprinted elsewhere in this issue. The exact position of the problem to-day will be understood from the fact that Mr. Neilson, in discussing the possibilities of gas turbines and the different plans on which they may be devised, does not at any point refer to an actual engine of one or other of his types, which has done anything of practical importance. No doubt, if he had so chosen, he could have hunted out from the records of the Patent Office, various specifications of inventions on this subject; but a patent is one thing, and a successful engine is another, and for the present we must confess that there is no immediate prospect of seeing a practical gas turbine on the market. In the end, however, it will come, and its coming will be hastened or deferred according as our engineers are able and willing to spend time and money on investigations of such practical problems as those mentioned by Mr. Neilson.

The theory of the different cycles on which the gas turbine might be worked is, as Mr. Neilson's paper shows, quite clear and fairly simple; but at several points we are brought almost to a standstill from want of experimental data by which to test the validity and practicability of our theoretical conclusions. Mr. Neilson places in the forefront in this respect the question of the losses in pneumatic compression to high pressures (*a*) with reciprocating compressors; (*b*) with rotary compressors;

(*c*) with combination of the two types. The importance, for our purpose, of an investigation to give this information, is readily seen. In the ordinary reciprocating gas-engine, the gas is drawn into the cylinder, then compressed by the engine itself, and then exploded, thereby driving the engine. But in the type we are considering the compression cannot take place in the driving turbine, and a compressor must, therefore, be used, supplying compressed gas to a combustion chamber, from which after combustion it passes to the turbine. Now it would obviously be a great advantage to be able to use a rotary compressor, mounted on the same shaft as the turbine, as we should thus dispense altogether with reciprocating mechanism and be free also from many of the objections to which reciprocating compressors are subject—such as the heating of the gas by contact with the hot metal surfaces before compression commences, and the necessity to jacket the cylinder if high pressures are to be obtained. But at present we do not know enough about rotary compressors on the turbine principle to estimate their efficiency when high pressures are to be employed. Mr. Neilson points out that these engines seem as yet to have been employed only up to about 80 lbs. pressure, and—

> "Whether or not they are suitable for high pressures is a point which we want very badly to know about."

It will be noticed that in the abstract, given in this issue, of the paper by Mr. Meineke "On a Process for Operating Gas Turbines," it is suggested that the compression should be obtained from a turbine mounted on the same shaft as the motor turbine, and it is said that—

> "It should not be difficult to obtain very high pressure differences by inverting the process that takes place in a turbine."

That may be true, but it rather misses the point; for it is not so much the mere compression to high pressure that we are concerned with, as the efficiency of the engine which does it. If the losses in this pump are very great at high pressures, then the practical success of the turbine is at once challenged, as the available power of the engine, after supplying the compressor, may be very small or nothing at all. The importance of this "negative work" in the compressor must be kept in mind, and it is very desirable that we should have experimental data on the losses incurred with the different types indicated by Mr. Neilson, when used for high pressures.

The second point which Mr. Neilson marks out for investigation is the expansion of hot gases in divergent nozzles. The importance of this investigation appears in connection with the admission of the products of combustion of gas-fuel and air into the buckets of the turbine. After combustion the temperature of the gases will be very high, and if they are to be admitted at once to the turbine it will be necessary to have the blades cooled by circulation of water or otherwise. This is in many respects undesirable, and it has therefore been proposed to lower the temperature of the gases before admission to the buckets by letting them expand in a divergent nozzle till a degree of temperature is reached which the buckets can stand. By this means the heat energy of the gases is converted into kinetic energy, but of course there will be losses by friction in the nozzle and by radiation. Experiments, then, are wanted to give accurate information on the expansion of hot gases in such nozzles, and part of the investigation must be to find the effect of the pressure of the medium into which the gases expand upon the velocity of the gas in the nozzle. We have here to deal with very high velocities; and it has been stated, as Mr. Neilson observes, that if the chamber into which the gases expand be at, say, atmospheric pressure, there is a limiting velocity for the issuing gas, which cannot be increased no matter how much the pressure of the gas on entering the nozzle be increased, and that this maximum velocity becomes greater as the outside pressure is reduced. It is of importance to have experiments made on this point, as from them we could determine whether the efficiency of the turbine could be increased by decreasing the pressure in the motor chamber below that of the atmosphere; and we have also to find out whether such high velocities as 4,000 ft. per second, given by Mr. Neilson, can be

obtained from gases issuing from divergent nozzles into a medium at atmospheric pressure. Here again, therefore, there is good scope for research work, with a view to the development of the gas turbine.

The third and last point indicated by Mr. Neilson for investigation is the determination of the losses from radiation and transference of heat from gases to metals at high temperatures. The importance of this is obvious when we remember that we have to deal with gases at high temperatures which remain practically the whole time during which they are in the turbine chamber in contact with metal surfaces, so that there must be considerable heat losses, and consequently loss of efficiency.

When we have full information on these three points we shall have made a great advance towards a solution of the whole problem of the gas turbine, but there will still remain many matters requiring very careful consideration and investigation. A careful perusal of Mr. Neilson's paper will indicate some of these matters to the reader. The point we would emphasise, however, is that, although the practical difficulties at present seem great, none of them is of such a character as to lead us to believe it to be insuperable. Rather do we gain the conviction that in time they will all be solved, and a practical gas-turbine evolved. Mr. Rankin Kennedy, in his work on "Modern Engines and Power Generators," has expressed much the same opinion when he says (vol. ii., p. 42):—

"It is at present not the case that we do not know how to begin to make a combustion turbine for oil or gas; the difficulty is the great amount of time and expense required to bring the details to perfection,—an operation which can be effected only by actual experiments on a considerable scale of magnitude."

Later, in the same volume, he says (p. 107):—

"The stage has been reached where the enterprising capitalist is necessary to carry it to the commercial success which undoubtedly awaits the first successful turbine set to industrial work. It will be interesting to observe in the future whether the home or foreign engineers take up the subject first."

From some other remarks of Mr. Rankin Kennedy we think he rather under-estimates the practical difficulties still in the way; but in the main he is right that capital and time will bring the solution, and we sincerely hope that our engineers will not be behind those of other countries in spending both time and money on this problem.

Binary Vapour Engines.

THE advantage of allowing steam to expand in the cylinder of the steam engine was fully recognised by Watt and other investigators, but, on account of the want of boilers capable of raising steam of high pressure, the range of varying pressure, even assisted, as it was, by the introduction of Watt's separate condenser, could not be very great.

With the improvements introduced both in the materials used and in the construction of the boilers themselves, higher pressures became common, and the compound engine enabled marine engineers especially to utilise this form of engine with economical results. Higher pressures, with increased expansion of the steam in the cylinder being still called for, the triple and quadruple forms of engine with increased range of expansion became common.

A few years ago the Parson's steam turbine was introduced. This steam turbine showed that not only could a direct driving power be obtained as in the older forms of rotary engines, but that, unlike in the previous systems, through the adaptation of expansive action, economical results could be obtained.

The principle underlying this expansive working depends upon the action of a perfect gas, where a given volume when free to expand has the product of its volume and pressure always constant. That is to say, if the volume of the gas at any stage of the expansion be represented by v, and the corresponding pressure by p, then $pv = c$, is a constant quantity, and therefore $v = \frac{c}{p}$, that is to say, the volume of the steam at any point in the expansion is *inversely* as the pressure. From this we see that, at low

pressures large areas of piston are required if the correspondingly lowered pressure is to have a similar effect to the higher pressures acting upon their area of piston. Hence in the compound, triple, and quadruple forms of engine increased diameters are given to the pistons of the low-pressure cylinders. This entails increase of bulk and consequent addition of weight in the machinery. It is so far unfortunate that this is the case, as the thermal efficiency of the steam is really proportionately *greater* at low pressures than at high pressures. If we take various rising absolute pressures and consider the efficiency of the steam with a constant lower pressure, we find that the thermal efficiency does not rise in proportion to the increase of pressure. For example, let the steam be expanded from, say, a pressure p_1 down to a lower pressure p_2, then if p_1 have the value of, say, 90 lbs. and p_2 of 8 lbs. per sq. in. the corresponding temperatures will be about 320 degs. and 185 degs., then $\frac{320 - 181}{320 + 461} = \cdot 173$ is the thermal efficiency of the steam. If now we take a pressure of, say, 276 lbs., whose temperature is about 410 degs., we find that the efficiency is now ·258, from which we see that the increase in efficiency is at a much slower rate than the increase of initial pressure.

Previous to the successful introduction of the compound-engine, about 1854, some ingenious attempts were made in France to overcome the wasteful nature of the steam engine of that time. This was not by compounding, as pressures were still low, but by employing two fluids, one of which was much more volatile than the other.

Rankine * gives a description of such a binary vapour engine, which was invented by a Monsieur de Tremblay, about 1850. Steam and ether were employed. The steam, after acting upon the piston in the cylinder in the ordinary way, was exhausted into a series of pipes surrounded by the ether. This fluid picked up the heat from the exhaust steam and became volatilised, the gas so produced being used to propel the piston of another cylinder. After its action there it was allowed to pass through a set of pipes surrounded by a current of cold water, which caused condensation. The re-formed liquid was then pumped back into the evaporating vessel, to be again used as before. Experiments showed that if the combined indicated power of the binary engine be taken as 100, then the proportion due to the steam-engine was 62, and that of the ether engine 38.

Experiments have again somewhat recently been carried out in Germany with a binary engine, where sulphur dioxide has been used instead of ether, and, as in the case of the ether experiments, it was worked under a closed system, so as to reduce loss.

As in the case of the earlier experiments the power of the primary simple steam engine seems to have been increased about 30 per cent. when working as a binary arrangement. Sulphur dioxide, like ether, evaporates quickly and is easily condensed, and as these fluids can be used over and over again, an increase of power seems to be obtainable without an undue increase of cost for the working fluid.

Surely this should offer an attractive field for inventors, especially when the steam engine in any of its forms seems to have reached a point of efficiency not likely to be much surpassed.

* "A Manual of the Steam Engine and other Prime Movers."

Our Canals.

AT the autumn meeting of the Association of Chambers of Commerce, held in Manchester, the question of the improvement of our system of inland waterways was once more brought forward for discussion. Everyone who has given but the slightest attention to this question knows that the present situation is anything but satisfactory, and that this country is far behind the Continent and America in the development of inland navigation. We have on a previous occasion* shown what the German Government is doing to open up waterways for the transport of heavy and bulky goods from the great manufacturing centres to

* Cf. FEILDEN'S MAGAZINE, Sept., 1901.

the sea-border; so that we need not now dwell upon the inferiority of our own system, or make any further comparisons. All are agreed upon the facts, and the present problem is to find the best means of making our canal system adequate for modern needs.

As the Chambers of Commerce are composed of men closely associated with our industries, and therefore in the best position to discover existing faults and to devise adequate remedies, it is natural to expect that in bringing forward a scheme for the renovation and reorganisation of our canals, they would have reached something like unanimity of opinion. In this, however, we are disappointed; for after a lengthy discussion of various suggested solutions of the present difficulties, the Association of Chambers of Commerce has been unable to give the requisite majority for any one of them. When we consider the principal scheme proposed, however, we do not wonder at the reluctance of many members to accept it. The resolution submitted on behalf of the Manchester Chamber was in these terms:—

"That, in the opinion of this Association, the time has arrived when the British Government should take over the whole of the canals of the country and work them in the public interest, or, in the alternative, that the canals should be transferred to a national public trust, with a Government guarantee, supervision, and control."

The chief argument brought forward in support of this resolution was the impossibility, under present conditions, of securing uniformity of working and of making proper arrangements for through traffic. Now we may readily grant that with a nationalised system we should have much better conditions for working than at present, and that we should also have a prospect of seeing the canals widened and deepened so as to give uniform gauge suitable for larger barges than can now be used; but it is not clear that these advantages can only be secured by nationalisation, nor yet that nationalisation is the most feasible remedy for present evils. In the first place, the railways are competitors with the canals, and the railway companies have considerable influence in Parliament. Is it likely, then, that these companies would sit quiet while their rival, at present somewhat weak, became suddenly transformed into a powerful State-aided undertaking? Only one result would follow—an agitation for nationalisation of the railways also; a step which is not at present within the field of practicability.

In the second place, it ought to be remembered that in this country there is no great love for Government departments. The spirit of the people has always in the past preferred to leave great trading undertakings in the hands of private persons or incorporations. Government management has come to be recognised as inseparable from objectionable "red-tape," and, worse than all, Government control puts an end to competition.

Finally, the cost of nationalisation even of the canals alone, which represent a capital expenditure of nearly £34,000,000, is in itself sufficient to render Parliamentary action in this direction extremely improbable. It is of course argued that it would be a profitable investment for the Government, and that Canal Stock would find ready subscribers. But it must be remembered that even this capital expenditure would be quite inadequate for the purpose if the object of nationalisation is to put our canals on a proper footing. Many of the canals would require to be almost entirely remade, and the widenings, deepenings, and erection of new locks would demand a very heavy expenditure; while the time required for this work would involve a postponement for a considerable number of years of any prospect of an adequate return for the money. For all these reasons, it appears to us that nationalisation of our canals, however satisfactory the results might be, is not at present a practicable scheme.

A scheme of a somewhat similar nature was embodied in a Bill introduced last session by Sir John Brunner. The object of this Bill was to enable municipalities to work disused canals, and it is interesting to note that Sir John agreed that nationalisation of the whole system would be a preferable solution of the problem, but maintained that something should be done

at once to allow of unrestricted use of the canals.* We agree heartily with this latter contention, but not with the means by which he proposes to carry out his object. Municipalisation has already gone much too far, and to allow any of the canals to fall into the hands of the municipalities would be in our opinion fatal to real progress. These bodies are jealous of all companies engaged in similar trades to their own, and put as many obstacles as possible in their way. If once a beginning were made by the municipalisation of disused canals, we should soon hear a clamour for further extension of the principle and for local control of all canals. That such a scheme would be hopelessly impracticable, would not prevent its being advocated, and any one who has watched the actions of neighbouring local authorities in attempting to arrange the relatively simple matter of through-routes for tramways from one municipal area into the other, will realise at once that these bodies are the very worst possible to be entrusted with canal management. If, therefore, immediate action be necessary, let it be such as will lead to good results and not to a state of affairs as bad as, or worse than, that now existing.

In a problem so full of complexity it is not easy to suggest a practicable remedy; but if Parliament is to be invited to deal with the matter, there is one scheme which appears to us to deserve consideration. The great obstacle to progress at the present time is the fact that so large a portion of our canals is in the hands of the railway companies. Originally the companies were not to blame for this, but since they have acquired these canals, they have done next to nothing to keep them in good condition or to improve them as occasion requires. They are content with mere ownership, and may consider it to be in their own interests to discourage canal traffic as much as possible. As some of their canals are links between systems owned by companies, and part of the great through-routes between the industrial centres, they are able to obstruct most effectively any attempt at development of our inland waterways. Now this policy is, we believe, not in the true interests of the railway companies themselves, but further, it is a policy which ought not to be tolerated. Parliament is responsible for this state of affairs, and Parliament ought to end it. Half measures were taken some years ago when by statute the further purchase of canals by railway companies was forbidden, but half-measures will not do. If a Bill were passed by Parliament to compel railway companies to sell their canals either to existing companies or new companies, we believe a great stride of progress would be made.

That the railway companies would not be solidly united against the scheme we propose is shown by the fact that the Chairman of the Great Central Railway Company stated at the last half-yearly meeting that he was prepared to sell the company's canals at a reasonable price. We hope this offer will be accepted, and also that where the same willingness to sell is not to be found, Parliament will step in and compel a sale. If this be found impossible or impracticable, the only alternative is to compel the railway companies to keep all their canals which form links between other systems in as high a state of efficiency as those which they join. But, so long as railway ownership exists, we fear we cannot expect to see our canals brought into full accordance with modern requirements.

* See *Daily Chronicle*, April 30, 1904.

High-tension Transmission.

THE increasing employment of the high-tension transmission system is a most important feature of modern electrical practice. Its further development cannot fail to exercise a noteworthy influence upon the industrial progress of new countries in all parts of the world, and upon the restoration of prosperity and renewed vigour to other countries whose civilisation dates back into the early days of mankind. We need scarcely mention the extensive applications of long-distance transmission that have been made in the

United States and Canada. The most noteworthy of these are already familiar to our readers. Electricity generated at Niagara and other natural sources of energy is being conveyed to places far distant from the originating source and applied for lighting, heating, and power purposes. The rest of the world is now following the example of the United States, and in Mexico especially great activity is being displayed in the utilisation of water-power for the generation of electricity, which is transmitted to considerable distances for light and power purposes.

A Remarkable Mexican Power Scheme.

One of the most noteworthy installations of the kind is to be found on the river Duero, in Mexico, where water-power is utilised to the extent of about 283 cub. ft. per sec., the pipe line being no less than 3,300 ft. long, and the mean diameter more than 5 ft. The generator has a capacity of 1,250 kw., and furnishes 2,300-volt three-phase current at 60 cycles, which is transformed to 60,000 volts for the purpose of transmission over a distance of 101 mls. The details of the line differ materially from those hitherto adopted, notably in the use of hard-drawn copper cable instead of solid metal, while some novel features are also to be found in the design of the insulation towers and in the unusually long spans between supports. At Guanajuato, the potential is stepped down to 15,000 volts; and from the switchboard at this station, six 15,000-volt distribution circuits convey current to various mines and mills, where the potential is further reduced to 460 volts for use in motors. Current is also supplied at 2,100 volts for the lighting system of Guanajuato city, and a branch transmission line is carried to a sub-station at Irapuato, on the Mexican Central Railway. This interesting project was executed in a remarkably short period of time; for, although construction was not commenced until the autumn of 1902, the whole system was ready for complete operation by October, 1903. Apart from its rapid and efficient realisation, the undertaking serves to demonstrate in a striking manner the valuable aid afforded by modern electrical practice to industrial and municipal development.

A 40,000-volt System in Italy.

Turning to the old world, we find a most interesting example of high-tension transmission in the installation, which commenced work in July last, at Nembro in Lombardy. Although not involving very great power, this undertaking deserves special mention as an illustration of the economy and reliability of high-tension plant, and also for the reason that the voltage adopted has hitherto been unprecedented in Europe. Power is derived from the Serio, a mountain stream coming down from the Alps and flowing through the Seriana Valley. At present only 2,000 h.p. has been utilised, but the conducting line is designed for the transmission of 4,000 h.p., the generating station being established at Gromo, a distance of 22 mls. from Nembro, the place where current is applied. Provision was contemplated at first for the transmission of 2,000 h.p. by three-phase alternating current at a potential of 30,000 volts; and it was assumed that the additional supply of 2,000 h.p. (making 4,000 h.p. in all) would be transmitted by duplication of the original line. For reasons which we need not here explain the above method of procedure was found to be undesirable. Although the establishment of a duplicate transmission-line is generally a safeguard against breakdowns, this advantage would not apply to a case such as the present, where both lines would be carried on the one set of poles. Consequently it was decided to design the system at the outset for the transmission of 4,000 h.p.; and, in order to limit the potential loss to less than 5 per cent., the potential was increased to 40,000 volts. The power station at Cromo village has been built at the foot of the mountain on which the pipe line is laid. The turbine, generator, and transformer practically form a single unit, an ingenious arrangement which was advocated by Mr. C. H. Merz and Mr. W. Maclellan in their paper on "Power-Station Design,"

read before the Institution of Electrical Engineers this year. The same idea has already been realised in connection with the 20,000-volt installation at Como, and obviates various complicated cross-connections and coupling devices. The total length of the transmission line is about 20 miles, following the valley of the Serio to the cotton mills at Nembro: where the potential is reduced to 500 volts before supply to the adjacent mills. The operation of this installation will be watched with interest, and all concerned are to be congratulated on the advance thereby made in the development of the high-tension transmission system in Europe.

An American 80,000-volt Experimental Line.

Judging from recent experiments, it is probable that voltages considerably higher than those hitherto employed, will be adopted in the near future. In this connection we may refer to an experimental line which was established last year between the Kern River and Los Angeles in California, for the purpose of ascertaining the practicability of making a large increase in the voltage originally proposed for the Kern River transmission system. The copper had been proportioned for a working tension of 45,000 volts, but it was recognised that the contemplated supply of 10,000 h.p. would be insufficient for the requirements of Los Angeles. Hence the suggestion was made that the potential should be increased by 50 per cent. Nine types of insulators were tested with an average potential of 80,000 volts, and the general results were quite satisfactory. It was finally decided to adopt a brown porcelain insulator of large size, and made in four pieces, with the inner petticoats spread so as to permit the inside to be cleaned at regular intervals. The results of the experiments point to the necessity for periodical cleansing in this manner, and it is believed that such treatment will keep the insulators as efficient as when new. Subject to this condition, the engineers to the company felt justified in saying that the adoption of 66,000 volts of a working potential would present no difficulty whatever. As the completed transmission-scheme will convey 20,000 h.p. for a distance of 125 mls., it will readily be realised that the increase upon the originally estimated voltage will result in a very important saving.

High-tension Direct-current Transmission.

All the installations to which reference has been made are employed for the distribution of alternating current, which is less desirable than direct current, because less efficient use is made of the conductors, and because of inductance losses in the transmission line. With the object of obtaining reliable data as to the resistance of insulators for direct current, as compared with that for alternating current, some experiments have been conducted by the Compagnie de l'Industrie Électrique et Mécanique, of Geneva. For comparative purposes, current of each variety was employed at potentials up to 7,000 volts; and, in spite of the fact that the conditions were unfavourable to the direct current, the results were distinctly in its favour. The insulators, without exception, were able to resist much higher voltages, and the same effect was observed in the case of insulating materials. We need not here refer in detail to the investigation, as a paper on the subject is reproduced elsewhere in this issue.

That most important developments will follow this demonstration no one can doubt. By using the earth as the return conductor, the distances hitherto covered with any given voltage by alternating currents may be doubled by the employment of direct current. This means that the area over which power may be distributed from a waterfall or river can be increased fourfold, a fact that should be of immense value in the utilisation of natural sources of energy in various parts of the British Empire. It ought also to result in the establishment of numerous electricity works in the coal and iron producing districts of England, and consequently in the supply of current at low rates throughout the greater portion of the country.

The Engineering Plant at the New Savoy Hotel.

By SYDNEY F. WALKER, A.M.Inst.C.E., M.I.Mech.E.

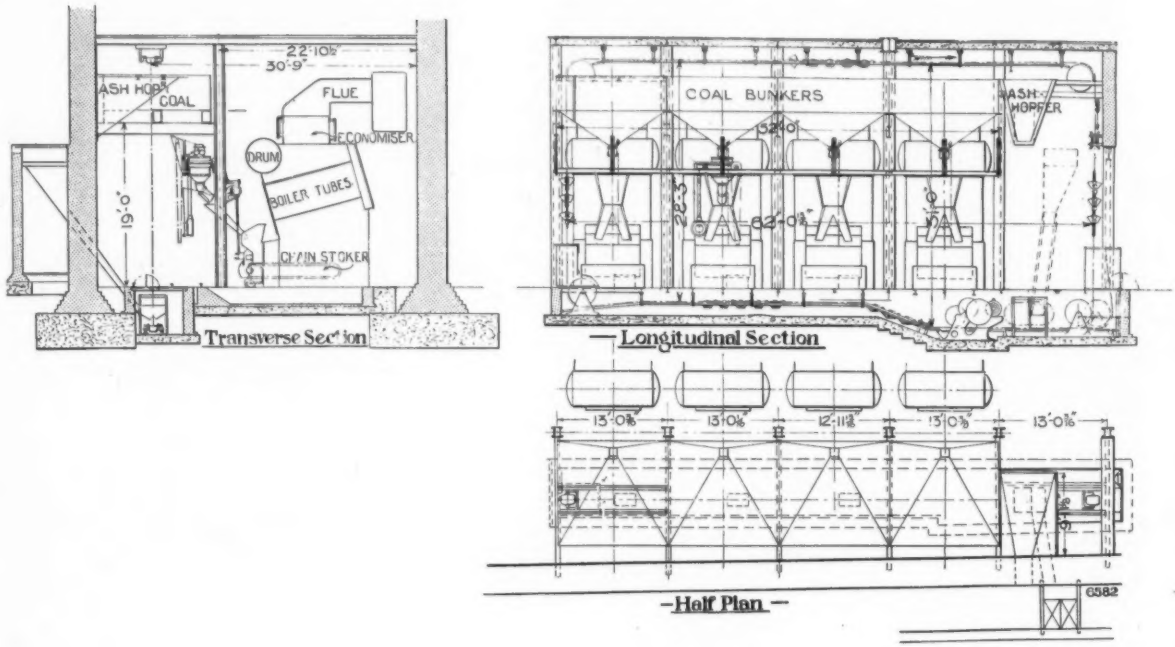
PROBABLY one of the best examples of the thorough adaptation of engineering facilities to modern requirements in hotel life is to be found in the new part of the Savoy Hotel, which has recently been opened. The whole of the plant is self-contained, and steam for all purposes is generated on the ground, in water-tube boilers of the latest modern type. Not only is the electric current generated for the 6,000 incandescent lamps that are in use, but also for driving the electric motors which, to the extent of 500 h.p., are distributed about the building, driving fans for ventilation, lifts, accessories for the kitchen; and in addition the current supplies the electric heating appliances and accessories to the toilet table.

The Boiler Plant.

There are three basement floors below the level of the Strand on which the new portion of the Savoy Hotel stands, and the boilers are fixed on the lowest basement. Advantage is taken of the difference of level to arrange the coal supply economically, and so that it is not a nuisance to the neighbourhood. The coal is tipped from a cart, in a side yard, into a receiving hopper, connected by a chute with one of Babcock & Wilcox's Silent Gravity Bucket Conveyors, of 15 tons per hour capacity, fixed in a trench 20 ft. below the level of the street where the coal is tipped. The conveyor delivers the coal automatically into the bunkers, of which there is one for each boiler. From the bunkers the coal descends by gravity, through a portable weighing machine, to the hoppers of the chain stokers of each boiler. There is one portable weighing machine for the four boilers, and this is brought opposite each hopper as required. The capacity of the weighing machine is 5 cwts., and the operation of weighing the coal consists merely in filling the machine, and then allowing the coal to pass to the stoker hoppers. The same conveyor passes under the ash pits, carrying away the ashes, and delivering them to a storage hopper in the street above, from which the carts which remove them are loaded by hand. The conveyor is driven by a 3 h.p. electric motor, taking current from the supply service. The boilers are four in number, of Messrs. Babcock & Wilcox marine type, with solid drawn tubes. Each boiler has a heating surface of 2,130 sq. ft., and an economiser surface of 280 sq. ft., and is also fitted with a Babcock & Wilcox superheater capable of adding 150 degs. Fahr. to the steam after it has left the boiler. Each boiler is fitted with a chain-grate stoker, 6 ft. 6 in. wide and 8 ft. 6 in. long, the whole of the stokers for the four boilers being driven by two electric motors, one connected to each end of the driving shaft. The fire grate area of each boiler is 55¼ sq. ft., and the four boilers with their accessories are stated to be capable of evaporating 40,000 lbs. of water per hour. There are two boiler feed pumps, one a direct-acting steam pump, and the other an electrically driven three-throw ram pump. The two are capable of delivering 6,000 gallons an hour to the boilers. There is an overhead storage tank capable of carrying 12,000 gallons, to which the suction of the feed pumps is connected. There are also three exhaust-steam heaters, one for the boiler feed water, and the other two for the hotel hot-water supply.

The Electricity Generating Plant.

As space is of great importance, it will not surprise anyone to find that turbo-generators are employed. They are of the Westinghouse-Parsons type, two of



DETAILS OF BOILER AND CONVEYOR ARRANGEMENT; THE SAVOY HOTEL.

200-kw. output, and two of 100-kw., all furnishing continuous currents at 100 volts. There is an accumulator consisting of 51 Tudor cells, capable of giving 700 ampères for 1 hour, or of discharging at the rate of 1,000 ampères for short periods. There is also a reversible booster having a capacity of 17½ kw. for charging the accumulators; and a milking booster. The charging booster is necessary, as the accumulator, when being charged, has a higher pressure than that of the generator. The booster, which is simply a motor generator, converts the generator pressure of 100 volts to the charging pressure, 130 volts, or thereabouts; and it also allows the current from the accumulator to be used on the regular supply service, if required by a temporary heavy demand, without any other arrangement, the motor generator reconverting the current delivered by the accumulator to the service pressure. The milking booster is for the purpose of bringing up any particular cell that is run down, without disconnecting. It is again a motor generator, arranged to convert the service pressure to that required for a single accumulator cell. The switchboard is of white marble, is 34 ft. in length by 7½ ft. in height, and has 17 panels 2 ins. thick. In addition to the usual arrangement for the generator and feeder circuits, switches are provided which enable connection to be made with the Charing Cross and Strand Electricity Supply Mains, in case of necessity. The whole of the lighting and power service is provided by the above, except that of the ammonia compressor for the refrigerating plant. The whole of the generator plant is by the Westinghouse Co.

The Lighting Service.

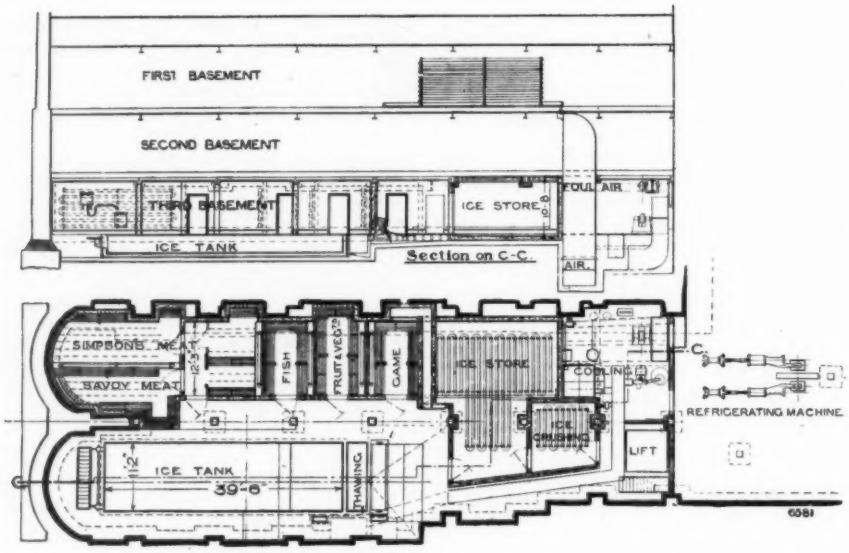
This has been fitted up by Messrs. Strode & Co. As already mentioned there are 6,000 incandescent electric lamps, all fitted in chandeliers, except those to be described, and there are no arc or Nernst lamps. The Entrance Hall, the Foyer, and the Dining Room are lighted with Linolite lamps, an arrangement recently introduced, in which the incandescent lamp filament is stretched out in a straight line, instead of being formed into a curl. The straight line filament, or "Line o' Light," is enclosed in a hollow cylinder, one portion of which is made into a reflector. The inventors claim that they obtain a better distribution of light with this arrangement, and in the case of the Savoy Hotel the great advantage is obtained that the source of light is completely hidden, the lamps being fixed behind the moulding at the top of the wall decorations. In addition to the lighting circuits there are 250 heater plugs for hot plates, crimping irons, etc. The cables are all run in solid drawn steel conduits, arranged in the false floors between the different stories of the building. The distribution is on the system now commonly employed. Main cables, 30 pairs of them, are led from the main switchboard to main distributing boards on each floor, and from these sub-main cables are led to over 100 distributing boards. Each suite also has its separate meter, of which there are 120. There are 40 mls. of steel conduit, 150 mls. of cables, 4,000 switches, and 700 plugs for connections of various kinds.

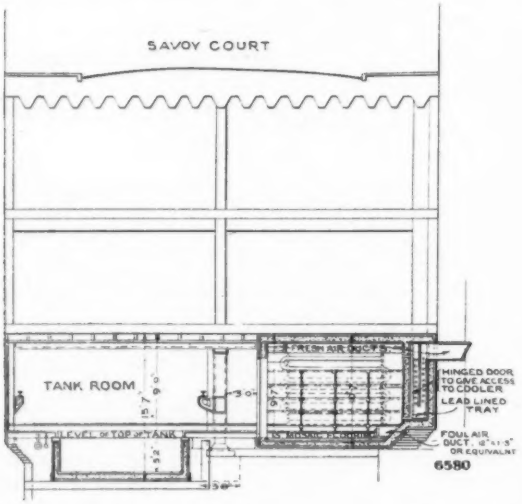
The Telephone and Bell System.

Messrs. Strode & Co. have also fixed a very complete telephone and electric bell system, enabling communication to be carried on between the different departments. Each bedroom can call the valet, waiter, and chambermaid, while at night the call is repeated on a master indicator fixed on the ground floor.

The Cold Storage and Ice Making Plant.

The whole of this has been fitted to the designs and under the superintendence of Messrs. Hal Williams & Bridges, of 60, Queen Victoria Street, E.C. The total capacity of the plant is 10 tons of ice per day, and in addition 20,000 cub. ft. of cold storage space. The plant is on the ammonia compression system, with brine circulation for both the ice tank and the cold chambers, and an air circulation for the cold chambers in addition. The ammonia compressor has two cylinders, both double acting, driven by a compound Robey engine, each of the two compressor pistons being connected to the tail rod of





SAVOY HOTEL REFRIGERATION PLANT: GENERAL ARRANGEMENT OF INSTALLATION.

one of the steam cylinder pistons. The compressors are arranged to be worked separately if desired. The hot compressed ammonia gas passes from the compressor to the atmospheric condenser, and from there to the expansion coils in the brine tank, from which it returns to the compressor. The ice tank and cold chambers are supplied with brine from the same main-service pipe, but that of the cold chambers is carried at a lower velocity than that for the ice tanks, this being accomplished by increasing the size of the pipes supplying the cold chambers. The ice tank is divided also into two portions, 2 tons of distilled-water ice can be made per 24 hrs. in one portion, and 8 tons of opaque ice in the other. Some of the ice made at the Savoy is taken to other hotels belonging to the same proprietors, and for this purpose an overhead railway has been fitted by Messrs. Herbert Morris & Botlerd. The opaque ice is used for the cold cabinets that are distributed throughout the building. There is an ice store capable of holding 50 tons, and a

special machine for cutting the distilled-water ice into small cubes for table use. The water used in the condenser is cooled in a Barnard tower fixed in one of the upcast ventilating shafts, and the foul air from the boiler and engine rooms, kitchens, and from the cold chambers is made use of in the process of cooling the condensing water. The air circulation for the cold chambers is derived from the ventilating system. The downcast supply is tapped, ducts are led from it to the cold chambers, and other ducts connect the outlet valves of the cold chambers with the system leading to the upcast shaft from the boilers, kitchens, etc., a fan at the shaft bottom leading the foul air to the shaft. The Barnard tower, consisting of galvanised mats hanging vertically, occupies about 20 ft. of the upcast shaft. The water from the ammonia condenser is led to the top of the tower, and allowed to trickle down over the wire mats, while the fan drives the current of warm air up through them. A small quantity of the cooling water is evaporated by this air, the cooling water being thereby reduced 20 degs. in temperature. The warm air used in the cooling tower enables a greater cooling effect to be obtained, owing to its greater capacity for moisture. In addition to the above, Messrs. Hal Williams & Bridges have arranged, in connection with the refrigerating system, special wine coolers in

SAVOY HOTEL REFRIGERATION PLANT: ONE OF THE SMALL COLD ROOMS.

SAVOY HOTEL REFRIGERATION PLANT: ONE OF THE "SERVICE" REFRIGERATORS.

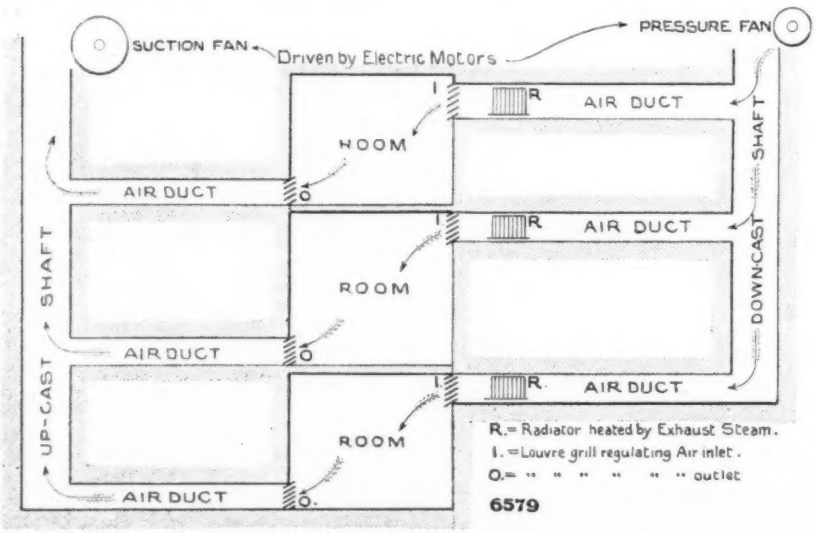
different parts of the building. The temperatures of the cold room are shown in the engine room by means of Callender & Griffith Electrical Temperature Indicators, which have been fitted by the Cambridge Scientific Instrument Co.

The Ventilating and Heating System.

This is also very complete, and has been carried out by Messrs. Rosser & Russell, of Whitehall, in connection with the Sturtevant Co. and the American Radiator Co. There is one downcast shaft and three upcast shafts, each having its own fan driven by an electric motor, supplied with current from the lighting service. The arrangement is a combination of the plenum and vacuum systems—that is to say, the air is forced down the downcast shaft, and sucked up the upcasts, the process being assisted in the case of the air from the kitchens, etc., by the fan at the bottom of the upcast shaft mentioned. Radiators are fixed in the path of the air for each group of rooms, the radiators being heated by the exhaust steam from the turbo-generators, and the quantity of steam passing into the radiators being regulated by a thermostatic valve in each. In addition, it is intended to clean the air on its way to the living rooms by passing it through a cleansing apparatus, which will also impart a certain quantity of moisture. The fresh air will enter the rooms by inlet valves capable of regulation, placed near the ceiling. The ducts leading the air from the downcast shafts to the rooms will be in the false floors, between two stories, in which the steel conduits for the electric cables are also fixed. The vitiated air is removed by valves in the neighbourhood of the chimney pieces, near the floor level.

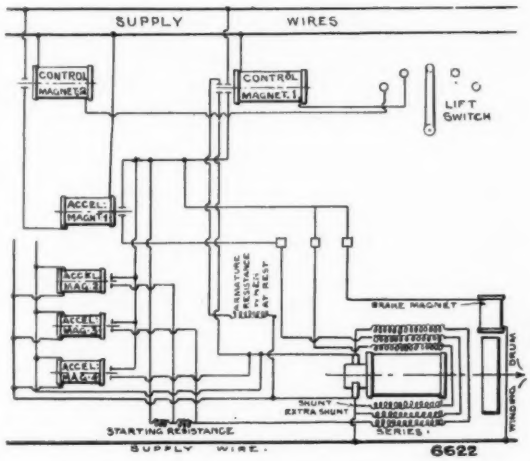
The Elevator System.

These are all supplied by the Otis Elevator Co. There are seven electric passenger-lifts, four luggage-lifts, and ten service-lifts in addition to the hydraulic lifts in the old building. The whole of the work of the electric lifts is performed by current supplied by the lighting service. The lift car itself is supported by ropes which are wound up and let out by a drum on the basement, the drum being



SAVOY HOTEL EXTENSIONS: DIAGRAM SHOWING THE SYSTEM OF VENTILATION.

driven by a shunt-wound electric motor, by means of two worms and wheels, and specially arranged buffers, so that there is no vibration, and the car rides quite easily. The drum also winds and unwinds the balance ropes. The shunt-wound motor has three magnetising coils, its regular shunt-coil, a second shunt coil, and a series coil. The second, or extra shunt coil, and the series coil are only put in operation when starting the lift, or when it is required to run slowly, as when nervous old ladies are riding. There is also the usual starting resistance. All of the operations in the process of starting, accelerating, and stopping are performed in the motor room, by a series of electro-magnetic switches, the latter being put into operation by a switch on the car. On the car, as those who have seen the Otis elevator will remember, there is a box with a handle which the attendant turns to the right or the left, according as he wants the lift to go in one direction or the other. When he puts his handle to the first contact he connects an electro-magnet in the motor room with the supply service, and this electro-magnet, when energised, pulls a contact piece into connection, completing the usual first connection when starting an electric motor. Current is turned on to the shunt coil of the motor, the extra shunt coil and the series coil, and to the armature, through the starting resistance. In addition another electro-magnet is energised at the same time, which pulls a band brake off its pulley. The motor then starts slowly. When the attendant moves the handle of his switch to the second contact, the circuit of the first of another series of electro-magnets is completed, which perform the operations usually performed by hand, cutting out the starting resistance by sections, the extra shunt coil, and the series coil. The first operation performed by the electro magnet that is energised when the switch on the car is turned to the second contact is, the circuit of the extra shunt coil is broken. This allows the motor to run faster, and then a series of electro-magnets arranged to come into operation, one after the other, as the motor increases its speed, by virtue of that increase in speed, cut out the series coil, and the starting resistance in succession, the motor gradually getting up its full speed. When near the landing place the handle on the car is put back to the first contact, and the reverse operations take place, the motor gradually slowing. When the handle is put in the centre all current is cut off from the control magnets, the brake is released and comes into operation, and as the armature of the first control electro-magnet returns to its position of rest, it completes another circuit in which the armature of the motor is included, the latter being then short circuited through a resistance. There are also emergency switches which come into operation in case anything happens to the lift, which cuts off the current, applies the regular service brake mentioned above, a special emergency brake, and short circuits the armature, etc. The service lifts are arranged on something the same lines, but are worked by pushes from the service floor.



SAVOY HOTEL EXTENSIONS: DIAGRAM OF CONNECTIONS FOR OTIS ELEVATORS.

High-Power Gas-Engine Plants in America.

By FRANK C. PERKINS, A.M.Am.I.E.E.

WHILE it is well known that the home of the high-power gas-engine is in Europe where it is so extensively employed, American engineers are waking up to the fact that there is a great field of usefulness for this type of prime mover, not only on account of its high thermal efficiency, but because it can be utilised with the chief fuel in the natural gas sections of the United States as well as with the waste gases from blast furnaces and coke ovens.

The accompanying illustrations, Figs. 1, 2, and 3, show the interior of the power-house as well as the gas scrubbers, gas-holder with meter and Scaife water purifying plant of the Penn-American Plate Glass Co. at Alexandria, Ind. This power-house contains three single-cylinder double-acting gas-engines of the Koerting type, each having a capacity of 600 b.h.p. To each of these engines is directly coupled a "Westinghouse" 400-kw. alternating current 3 phase generator constructed at Pittsburg, Pa. These alternators supply a polyphase current of a frequency of 50 cycles per second at a pressure of 440 volts, the current being utilised for lighting and driving the plant. These engines operate at a speed of 100 revolutions per minute, running without stopping from Monday morning till Saturday night. This service has been continued for the past two years, using natural gas for fuel without interruption; but, in case this fuel should give out, a novel mixing-valve has been provided which is operated by three hand-levers, noted at the right in the foreground of Fig. 2, one for the exhaust, one for natural gas, and one for producer gas, thus making it possible to instantly change over from natural gas to producer gas without stopping the engine. The illustration, Fig. 3, shows the exhaust pipes, scrubbers, and gas-holder, and in the background in the centre are seen two horizontal compressed-air receivers for starting the engines. During the winter this space is closed in, radiating steam coils preventing freezing taking place.

The use of waste blast-furnace gases for power-generating purposes is now past the experimental stage as will be fully recognised, when it is noted that, at the Lackawanna Steel Works, at Buffalo, two power-houses are in operation whose ultimate output will be 40,000 h.p., nearly half of which is already being developed. Fig. 4 is from a recent photograph of the interior of power-house No. 1, which is equipped with eight twin Koerting two-cycle double-acting gas-engines, each having a capacity of 1,000 h.p. Three of these twin engines are direct connected to 500-kw. continuous current Sprague-Lundell generators, supplying a current of 250 volts pressure operating at a speed of 100 r.p.m.

The remaining five engines are direct connected to 3-phase alternating current generators, each having an output of 500 kw. These machines supply a polyphase current of 440-volts pressure, with a frequency of 25 cycles, and were constructed by the General Electric Company. This power-house is 730 ft. long, and an immense pipe is installed along one-half of its entire length, supplying these engines with waste blast-furnace gases, the gas-engines occupying about 340 ft. of the south half of the building.

Fig. 5 shows the gas-blowing engine installed in the other power-houses of the Lackawanna Steel Co., which will ultimately contain 16 engines of this type of 2,000 h.p., each making a total of 32,000 h.p. for this one power-house and a complete gas engine plant of 40,000 h.p. capacity. There are at present five of

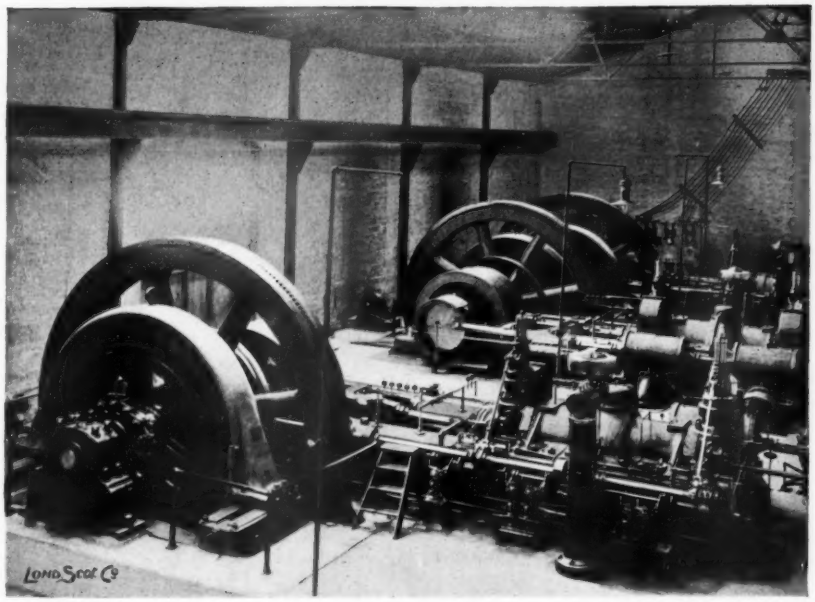


FIG. 1.—GAS-ENGINE AND ELECTRIC POWER PLANT OF THE PENN-AMERICAN PLATE GLASS CO., ALEXANDRIA, IND.

these 2,000 h.p. twin Koerting gas-engines in operation in this plant, each driving a vertical 76-in. by 60-in. blowing-cylinder, at a speed of 70 to 80 revolutions per minute. All of the above engines are operated with blast-furnace gas, and the remaining 11 units of the same size are nearing completion at the works of the De La Vergne Machine Co.'s works in New York City at the foot of East 138th Street. The blast-furnace gas supplied to these engines has a heat value of 80 B.T.U. per cub. ft., and consumes only about 10,000 B.T.U. per b.h.p. per hour, which corresponds to a heat efficiency of 25·5 per cent. based on the b.h.p. As will be noted by the illustration, these engines are of the vertical-horizontal type, the air-cylinder being arranged as a vertical element, and the gas-engine cylinders as the horizontal element. The gas-engines are of the twin Koerting double-acting type, designed at the works of Gebr Koerting Action Gesellschaft at Koertingsdorf, near Hanover, Germany.

Although of German design the engines are constructed in the U.S.A. by the American representatives, the De La Vergne Machine Co. of New York, the blowing-engines being constructed at Philadelphia by the Southwark Foundry Machine Co. The air-cylinders are 6 ft. 4 ins. diameter, with a stroke of 5 ft., while the power-cylinders measure 38½ ins. diameter, with a stroke of 60 ins. The engine air-pump cylinders are 38¼ ins., while the gas-pump cylinders are 45¼ ins. diameter. The details of construction as well as the method of operation may be more clearly noted in Fig. 6, which illustrates a 500-h.p. gas-engine and blower.

As will be noted by the illustrations, these gas-engines are double-acting, like a steam-engine; and therefore the crank-end and the head-end of the power-cylinder are similar, the admission-valves being located in the valve-boxes, which are bolted to the cylinder-head. As the products of combustion escape through the slots or ports cast in the middle of the

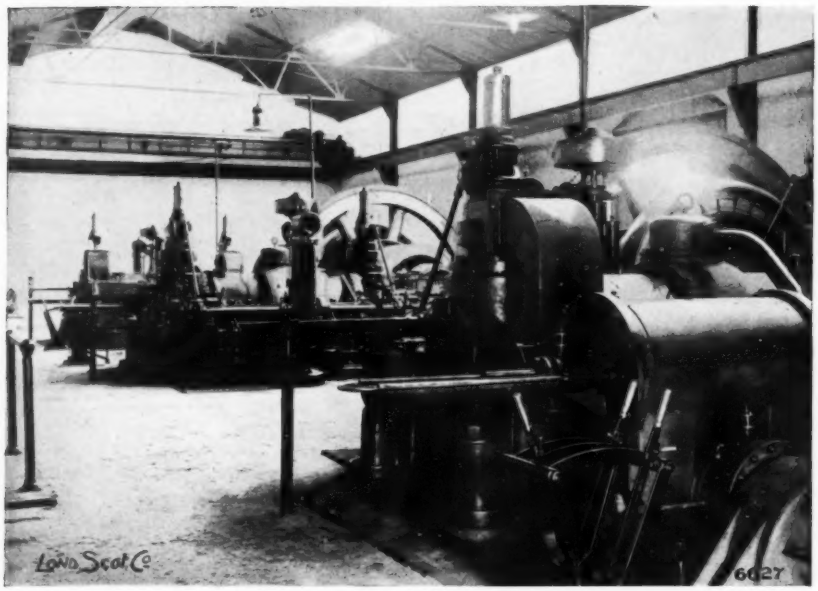


FIG. 2.—500-H.P. SINGLE-CYLINDER DOUBLE-ACTING KOERTING GAS-ENGINE AT THE POWER-HOUSE OF THE PENN-AMERICAN PLATE GLASS CO.

cylinder from where the exhaust-pipe leads, no exhaust-valves are required. The slots are covered by the piston itself, and for this purpose it is made very long and is packed at each end by self-closing spring rings. Two double acting auxiliary pumps, one for the gas and one for the air, are provided, by which the combustible mixture is admitted to the working cylinder. In designing these pumps they are so proportioned that their combined action also secures the proper mixture for perfect combustion. The compression spaces of the pumps are divided so that the crank-ends of the air-pump and gas-pump discharge into the crank-end of the power-cylinder. The head-ends of the pumps discharge into the head-end of the power-cylinder; the gas and air being compressed by the pumps to about 9 lbs. per sq. in. It will be noted from the plan, Fig. 6, that the piston is at the outer dead-centre, and the exhaust ports are exposed toward the opposite or head-end of the cylinder. The instant the cylinder begins to uncover the exhaust-ports, the pressure of the residual products of combustion in the cylinder falls to that of the atmosphere. As soon as this takes place, the inlet valve is opened and a fresh charge is forced into the cylinder by the pumps. The valve-gear of the pumps and working cylinder is so arranged that air only is supplied first, to separate the burned gases from the fresh mixture, and afterwards the air and gas mixed in proper proportion. The mixture of air and gas is produced only at the inlet to the cylinder, there being no storing of it; thus representing an advantage, it is claimed, over engines that keep more or less of the combustible mixture outside of the working cylinder. As soon as the exhaust-ports are covered by the receding piston, the air and gas pump pistons also arrive at their dead-centre position, and the supply of mixture is interrupted. The inlet-valve closes, and the charge is compressed in the cylinder, till, at the dead

point of the stroke, ignition takes place. At the next movement of the main piston, the ignited charge expands till just before arriving at the other dead-point, when the piston uncovers the exhaust-ports again and allows the consumed charge to blow out, while on the opposite end of the piston the same operation takes place.

The eight direct-current and alternating-current generators of 8,000-h.p. capacity in power-house No. 1, operated by double-acting gas-engines, supply current for operating the steel plant. Electric motors are not only used for the unloading devices at the ship canal, but also on the travelling cranes, the hoists to the blast furnaces, electric locomotives at the Bessemer-steel plant and at the rolling-mill where live rolls and various saws, rail straighteners and other tools are electrically driven. This great power-plant will also supply current for operating the new rolling-mill, for plates and structural steel, and also the electric charging-machines for the Siemens-Martin open-hearth plant, and the cranes used for handling and stripping the ingots from the moulds.

Each of the engines of the duplex horizontal Koerting type drives the electrical generators at a speed of 100 revolutions per minute. These engines have working cylinders 2 ft. in diameter, with a stroke of about $3\frac{1}{2}$ ft. They are controlled by piston valves, the air and gas pumps being driven by an eccentric gear from the main shaft. The regulation of power is effected in the following manner: when the load on the engine is reduced, the gas-pump begins to furnish gas at a correspondingly later period, thus discharging a diminished quantity of gas into the working cylinder. This is accomplished either by the valve-gear of the pump and controlled by the governor,

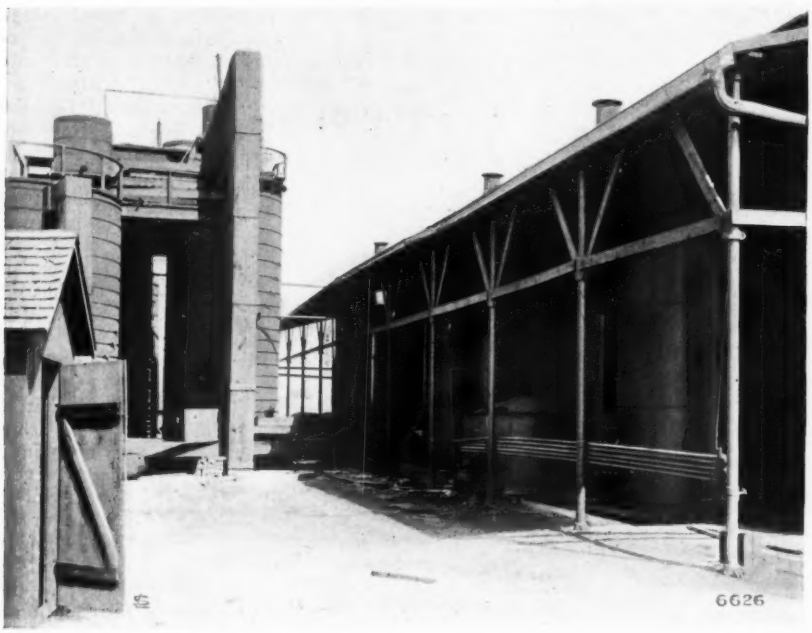


FIG. 3.—GAS SCRUBBERS, GAS-HOLDER, EXHAUST PIPE, AND SCAIFE WATER-PURIFYING PLANT OF THE PENN-AMERICAN PLATE GLASS CO.

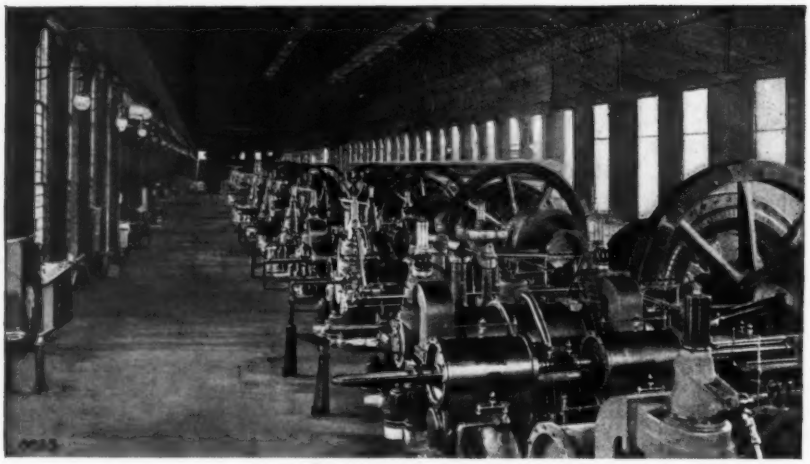


FIG. 4.—INTERIOR OF POWER-HOUSE, LACKAWANNA STEEL WORKS, BUFFALO.

or by a by-pass located between each pump and respective compression-channels which lead to the inlet valve on the main cylinder. The throttling device in this by-pass is also under the control of the governor. It will thus be noted that the engine operates with a variable amount of mixture, and that correspondingly more or less air is sent first into the power cylinder. This air stays near the middle of the cylinder, while a combustible mixture remains at the heads of the cylinder near the inlet valves and igniters. It is stated that the peculiar shape of the cylinder-heads prevents mingling of the layer of air with the following mixture of gas and air. For the ignition of Koerting engines there are provided two

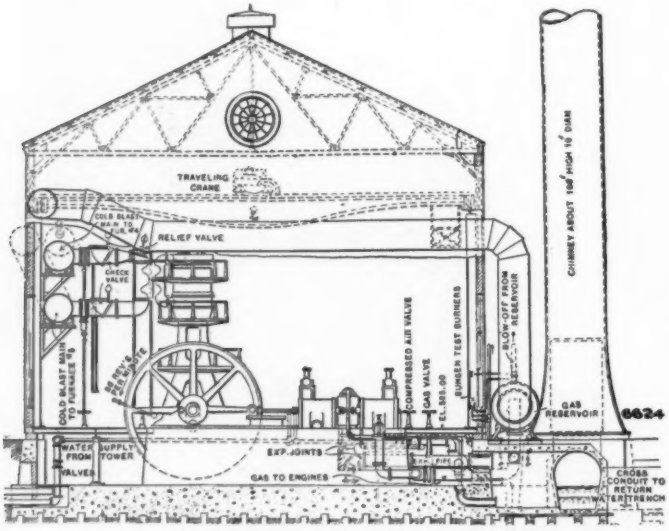


FIG. 5.—2,000-H.P. TWIN KOERTING DOUBLE-ACTING GAS-ENGINE AND BLOWING-ENGINE AT POWER-HOUSE OF THE LACKAWANNA STEEL CO., AT BUFFALO, N.Y.

spark coils at the end of the power cylinder. These are operated by a separate shaft driven by spur gearing from the cam shaft. The gear on the igniter shaft is not fast, being connected with a sleeve having a feather which is set spirally around the shaft, so that by a sliding movement of the wheel, the igniter shaft may be set behind or in advance of the cam shaft. In this way the time of ignition can be changed during the running of engine so as to suit whatever kind of gas is being delivered; and at starting the point of ignition may be so set that ignition takes place only after the piston has passed the dead centre, and the engine is thus started very slowly without incurring any pre-ignition. Compressed air is used for starting the engine, a pressure of 150 lbs. per sq. in. being used for the blowing gas-engines, and about 100 lbs. per sq. in. for gas-engines driving electrical generators. For admitting the compressed air at the front and back ends of the cylinder, a piston valve is provided, as in a slide valve steam-engine; and this is operated from

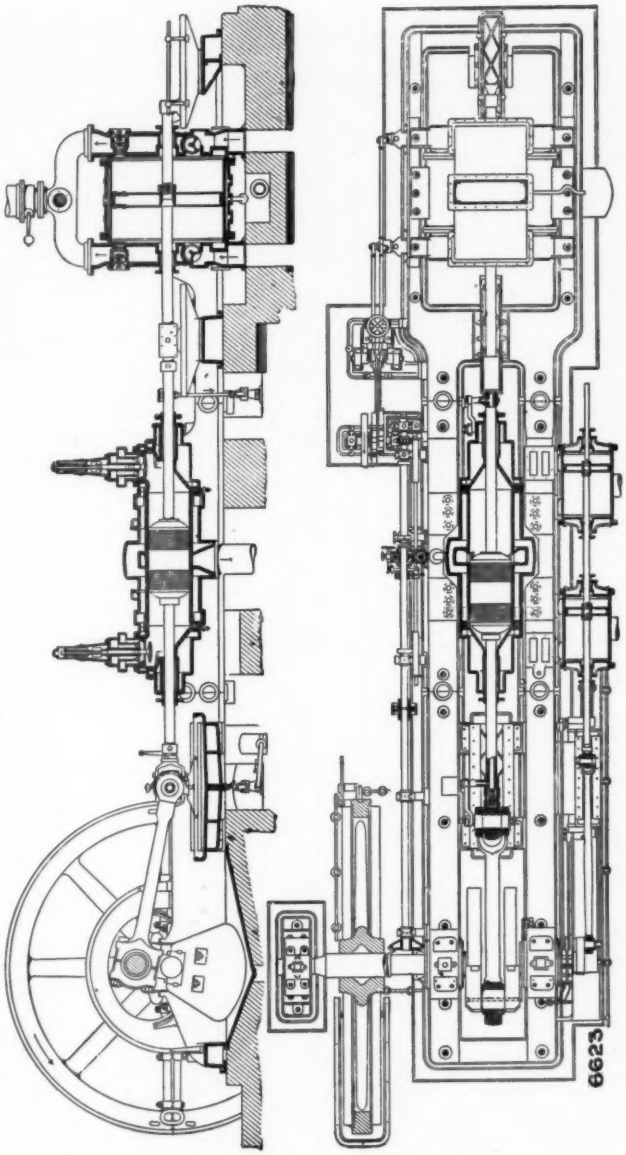


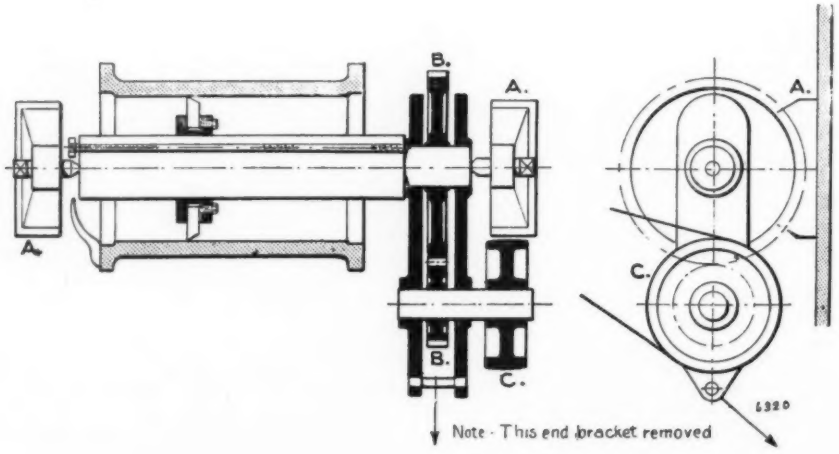
FIG. 6.—DETAILS OF 500-H.P. DOUBLE-ACTING GAS-ENGINE AND BLOWER.

the cam shaft by an eccentric which can be thrown in or out of gear by a clutch. The engines usually start off very readily after filling the cylinder with air twice. The power cylinder and the piston are water-cooled, the water entering a tube carried through the cross-head pin and hollow piston-rod, and returning the same way but on the outside of the tube. The cylinder walls are cooled throughout, except at the middle where the exhaust slots are located. The stuffing boxes in the cylinder-heads are also surrounded by water.

Westinghouse induction-motors are directly connected to centrifugal-pumps which supply the necessary cooling-water. The gas used by the engines is supplied by a 3-ft. pipe connecting with the blast furnace through a centrifugal washer which purifies and removes the dust from the waste blast-furnace gas. An electric motor is used for driving a fan, and a water-spray used in connection with the air blast causes the dust and impurities to be removed from the gas. In addition to the gas used in these engines, a large quantity is burned under the boilers for supplying steam to the various engines about the plant, and is also burned under the furnace stoves for heating the blast. It has been stated on good authority that the high-power gas-engine has reached the high thermal efficiency of 38 per cent., while that of the best triple-expansion steam-engine does not exceed 25 per cent. This is certain evidence that the high-power gas-engine will under certain conditions find a vast field of usefulness in the future.

Cylinder Boring Arrangement.

THE illustration is that of an arrangement most successfully used to bore locomotive cylinders in place; it takes very little setting, the bar running between centres, which are in cast-iron brackets *A A* fixed to frame of engine. Two ordinary lathe change-wheels *B B* are used, forming spur wheels and pinion, a small pulley *C* being fixed to pinion spindle. The bar may be driven by a bolt from any machine or shaft in close proximity, in this case it was driven from a pulley on top shaft of radial drill; in case of cylinders set at an angle, a grooved pulley and rope may be used. It will be readily seen that all strain of belt is taken off the bar, being kept in tension by a weight on floor, or by a small chain or rope attached to opposite side frame. This ought to be a handy and valuable tool in a locomotive repairing shop. C. R.



The Production of Iron and Steel by the Electric Furnace.

By W. McCLURE.

SINCE the first proposal to manufacture iron and steel by electro-metallurgical means was made six-and-twenty years ago by Siemens, numerous attempts have been made to devise a suitable process. Many of the suggested methods reached no further stage of development than that of forming the subject-matter of a patent specification; others have reached the experimental stage, and one or two have found a field of commercial utility and appear to be pioneers of an established industry.

Where the electric furnace has found success on a commercial scale in connection with iron and steel, has been in connection with two special problems out of the several that have been attacked by electro metallurgists. These are the manufacture of special steels and the production of ferro-alloys. The main problem, namely, that of the direct reduction of iron from its ores by a process similar to those usually adopted, except that the heat produced by an electric current is utilised to replace that derived from the combustion of carbonaceous fuel, is at present handicapped by the greater cost of heat electrically generated.

This question of energy-cost, coupled with that of transportation, is of equal importance with that of the supply of ore, and in fact, as has been recently pointed out, the location of iron-producing centres has been determined not so much by the proximity of iron-bearing measures, as by the availability of the necessary energy for the reduction and refinement which, in ordinary practice, is supplied by coal or coke.

The utilisation of electric energy is limited, therefore, by this consideration, and it is only in those areas where water-power or blast-furnace or other poor gases are available that there can be any hope of successful commercial application of the electro-metallurgical method in the smelting of iron ores.

In order to realise what this means it will be profitable to look a little closely into the question of the quantity of electrical energy absorbed in the production of one ton of pig-iron, and also to inquire into the price paid for electrical energy. Keller,* of Paris, states that he has determined experimentally, that one metric ton (2,205 lbs.) of pig-iron requires ·25 kw. year, that is 2,190 kw. hrs. for its reduction, not including the 350 kilos. of coke required for the reactions. Further, Dr. Goldschmidt† states in a report on the Stassano process, that 2,510 kw. hrs. were consumed in the production of one metric ton of carbon free iron. Another estimate for the Stassano process for one ton of iron gives 2,944 kw. hrs.; thus it will be seen that an average may be struck at 2,500 k.w hrs.

Now, as to the cost of electrical energy, this varies within wide limits according to the method of generation. The following figures taken from various sources will enable a basis to be formed from which it will be possible to compare the competition of the blast-furnace with the electrical process of smelting. For a kw. year, Gin assumes £3 6*s.* 8*d.*; Stassano and Keller, £2 18*s.* 4*d.*; while Dr. Stansfield gives a price as low as £2 2*s.*, for current produced hydraulically in America. Another writer, A. F. Schneider, gives £3 2*s.* 6*d.* per kw. year for water-power generated current in the United States, placing steam generation at £6 5*s.*, under favourable conditions. In Great Britain, the cost for a kw. year may reach £6 5*s.*, where gas-engines are used, and £11 8*s.* for steam generation.

* Inl. Iron and Steel Inst., 1903. Vol. i. p. 190.

† *Electro-chemical Industry*, March, 1903.

Let it be supposed, however, that current can be supplied at £3 11*s.* 6*d.* per kw. year, and that 2,500 kw. hours are required in the production of one metric ton of pig-iron. The energy cost would then work out at £1 0*s.* 10*d.* By the use of electric power, however, some amount of fuel would be saved, and putting this at ·06 of a ton* of coke per ton of iron produced, the saving in this direction would amount to 5*s.* 1*d.* per ton of iron. It would therefore appear that, except where the price of coke is very high, the electrical method cannot favourably compete with the blast-furnace in the production of pig-iron. Keller, in a paper before the Iron and Steel Institute, states that there are localities in which the high price of coke would warrant the employment of the electric process, and instances Chile, Brazil, and New Zealand; but it must not be overlooked that imported pig-iron might be obtained here at such a price as might jeopardise the financial success of any scheme based on the electrical system.

Leaving now the main problem of the reduction of iron from its ores, let us look at the other purposes for which the electric furnace methods have been applied to iron and steel manufacture.

These have recently been classified in a lecture before the American Foundrymen's Association† as follows:—

(1.) Treatment of molten pig-iron as it comes direct from the blast-furnace for the purpose of refining and converting it into steel of certain grades. This may be called the electro-refining of steel.

(2.) Treatment of cold pig-iron, or a mixture of pig and suitable scrap, to produce iron and steel.

(3.) Production of various ferro-alloys by either of the following methods:—

(*a.*) Starting with a mixture of iron ores and ores of the metal to be alloyed; or—

(*b.*) Starting with a mixture of pig-iron and minerals to be reduced and alloy therewith.

The characteristic features of these processes were stated as follows:—(1.) The electro-refining of molten pig-iron direct from blast-furnaces, or cupolas, presents certain advantages over treatment of cold metal. For instance, the considerable amount of heat contained in the hot metal is utilised. Also, hot iron has a higher electrical resistivity than cold iron, so that when it is desired to conduct electrical refining by producing the required temperature by Joulean heat, this is more easily carried out by starting with hot metal. For refining purposes, furnaces of the resistance type, to be described later, seem well adapted; that is where the temperature of the bath is maintained by the generated heat of an electric current passing through the metal itself. (2.) The class of electrical furnaces employing this method comprises those in which the high temperature of the electric arc is used to start the process, and later when a sufficient quantity of molten metal has been produced in the hearth, the current is made to pass through the slag floating on top of the bath. The slag has a higher resistivity than the molten metal, and the heat thus generated is taken up by the fluid metal beneath. (3.) This class of furnace has been applied for a number of years with considerable success, and its value for the purpose is undeniable. It already occupies a permanent place in the metallurgical scheme, as steelmakers are dependent upon electrical methods for many ferro-alloys not otherwise obtainable, such as ferro-silicon having a high percentage of silicon, high-grade ferro-manganese, ferro-chromium, ferro-alloys of titanium, molybdenium, tungsten, vanadium, etc.

As to the cost of production by these processes, this will be considered when dealing with the various methods attempted by the several experimenters. For the present, however, it may be stated that the production of one metric ton of tool steel has been effected by Kjellin's method in his induction furnace, involving the expenditure of 800 e.h.p.-hrs.,* the cost for power being, in this case, about 5*s.* 3*d.* per metric ton of metal.

* Dr. Stansfield: "The Electrothermic Production of Iron and Steel:" Pro. Can. Soc. of Civil Engrs. 1904.

† By P. McN. Bennie, Niagara Falls.

* Stansfield, *cf. loc. cit.*

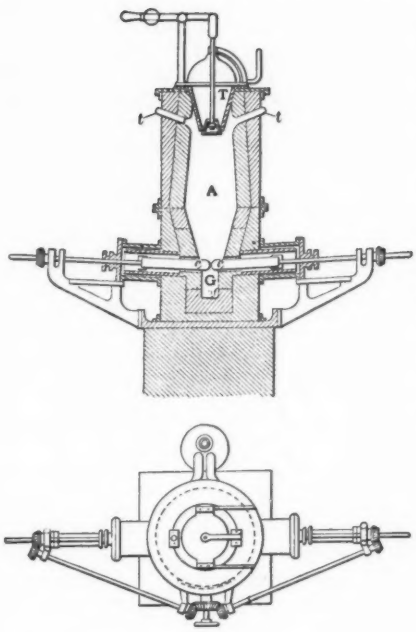


FIG. 1.—STASSANO'S SHAFT FURNACE.

As regards the processes proposed or actually attempted, the most important are those having their origin in Europe, where the bulk of the pioneer work has been done. The abundance of water-power existing there, and its utilisation for the manufacture of carbide of calcium during the acetylene boom, was responsible for the electric production of iron and steel having received so much attention there. When the crisis occurred in the calcium carbide industry, the question was what to do with the existing electric furnace plants, and European electro-metallurgists turned their attention to iron and steel.

Ruthenberg in the United States has been busily engaged on the problem, and the Canadian Government has shown some interest in the matter with a view of introducing the electric iron and steel processes in Canada, where also large water-powers and cheap iron ores are available.

Coming now to the furnaces used, they may be roughly classified in two types: (1) Those in which the heat is generated by the electric arc; and (2) those which are heated by the current passing through the charge under treatment, or through some portion of the furnace of high resistance.

In the first category may be placed the Stassano and Heroult furnaces, and in the second those of Harmet, Keller, and Kjellin.

The first Stassano furnace, illustrated in outline in Fig. 1, is a shaft furnace resembling in construction an ordinary blast-furnace, the ore being charged into the shaft *A* through a hopper *T*. The arc is maintained by alternating current between the two electrodes *c c*, which are movable to enable the resistance to be regulated. The molten iron and slag

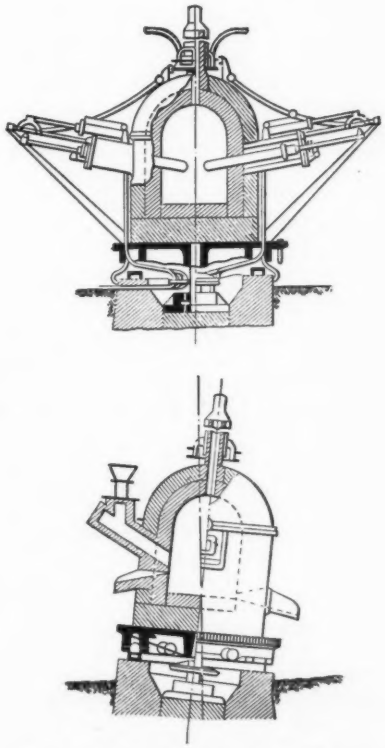


FIG. 2.—STASSANO'S BEEHIVE FURNACE.

collect in the crucible *G*, from which they are tapped off through the opening at *f*. The gases generated escape through the openings *t t*. This type of furnace has, however, recently been modified; Capt. Stassano having adopted the bee-hive form illustrated in Fig. 2. It has an arched roof, and is given both rotating and tilting motions when in operation. The electrodes, charging and tapping openings are clearly shown; while the opening at the top is for the purpose of drawing off the carbon-monoxide. Much care is exercised by Stassano in the preparation of the charge, which, in addition to the fluxes and carbon, which are pulverised, has added to it from 5 to 10 per cent. of tar, which binds the constituents together. Before being charged into the furnace the mass is broken up into 1-in. or 1½-in. fragments.

In criticising this furnace Dr. Stansfield* points out that, having regard to the position of the arc in reference to the charge, much heat is lost by conduction through the upper part of the furnace; and, further, that the waste gases, by passing through the arc on their way out, tend to escape at a very high temperature, thus wasting heat which might have been otherwise usefully employed. As regards cost of production by this furnace, figures given by Stassano and Dr. Goldschmidt showed that steel produced directly from local ores worked out at about £3 17*s*. 6*d*. per ton with ore at 12*s*. 6*d*. per ton and a consumption of 2,944 k.w. hrs. A 125-h.p. furnace working at Turin is reported as being capable of turning out 2,500 to 3,000 kgs. of metal per day with 120 to 140 h.p., the rate of production being 55 lbs. per h.-p. day. Current of 1,000 amps. at 80 volts pressure is employed.

The Keller Furnace.

This furnace, which is illustrated in Fig. 3, is of the resistance type, and is used for the direct production of steel. It is of similar construction to an ordinary blast-furnace, except that the crucible end is widened out to admit the insertion of four carbon electrodes which dip into the slag. The charge is admitted at the top in layers, the hot gases resulting from the reduction of the oxides in this case ascending through and heating the mixture. The utilisation of the heat in this way constitutes an advantage over furnaces of the Stassano type; furthermore the disposition of the electrodes in the Keller furnace enables the ore and carbon charge to be continuously introduced. To the left of the main furnace is a refining furnace furnished with two electrodes, the current passing from one to the other through the bath.

A furnace of this type working at Kerrouse was found by Keller to consume 2,800 k.w. hrs. in the production of a ton of steel. A series of important demonstrations was recently given by Keller before a Canadian Commission, headed by Dr. Eugène Haanel, sent to Europe to investigate the electric processes in use there. Some 90 tons of iron ore were used to demonstrate the economic production of pig-iron by the electric processes. The furnaces employed for these experiments were those used in the regular work of Keller, Leleux & Co. of Livet, for making by the electric process the various ferros, such as ferro-silicon, ferro-chrome, and so forth. The company at the time of the visit of the Commission were under contract to furnish ferro-silicon to the Russian Government, but generously interrupted their pressing regular work to undertake the making of experiments for the Commission.

The furnace employed was of the resistance type, and consists of two iron casings of square cross-section, forming two shafts, communicating with each other at their lower end by means of a lateral canal. The casings are lined with refractory material. The base of each shaft is formed by a carbon block. These blocks are in electric communication on the exterior of the furnace by means of copper bars. The carbon electrodes to which electric current is distributed pass two-thirds of their length into the shaft. The electrodes are prisms 72 cms. in diameter and 135 cms. long.

In starting the furnace the charge is introduced between the carbon blocks and the electrodes, which latter are then in

* *Loc. cit.*

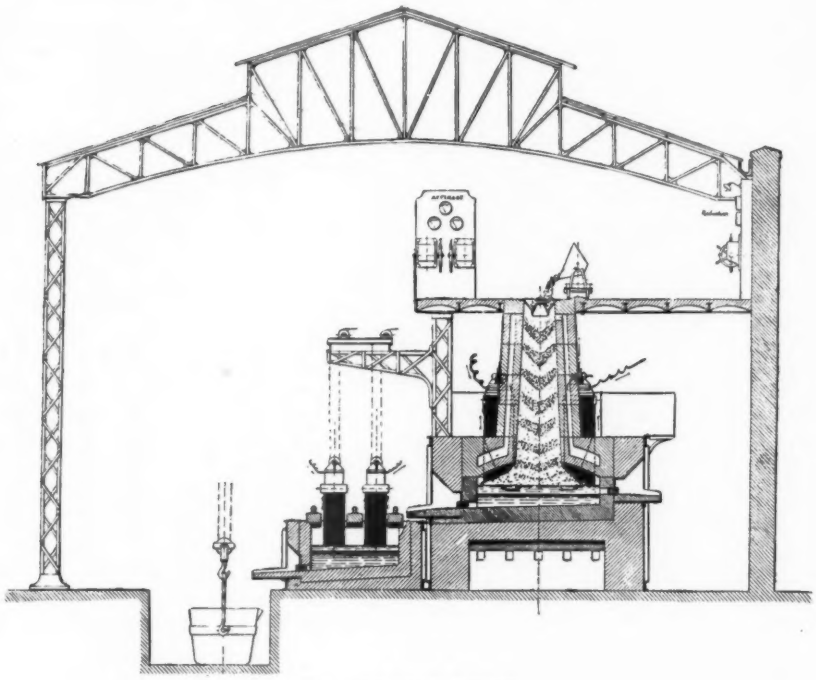


FIG. 3.—THE KELLER FURNACE.

their lowest position. The current passes from one electrode through the material to be reduced to the carbon block, from thence outside of the furnace by means of a copper conductor to the other carbon block, through the charge and to the other electrode. The current meeting with the resistance of the charge the latter is heated, the reduced metal flowing along the canal forms internal connection between the electrodes. The current in the exterior conductor diminishes as the amount of reduced metal increases. The electrodes are now raised, the charge continues until finally the electrodes occupy their normal positions, and the shaft below the electrode and between the electrode and the sides of the furnace is completely occupied with the charge. Under these conditions, but a small current flows through the conductor, the main current passing within the furnace from electrode to electrode. This ingenious arrangement enables the furnace to be worked continuously, without at any time varying excessively the load on the alternator. As a matter of fact the voltmeter and ammeter throughout the experiments were remarkably steady.

Three sets of experiments were made as follows :—

1. Electric reduction of iron ore and obtaining different classes of pig, grey white, and mottled.

2. Electric reduction of iron ore containing a definite amount of carbon in the charge, with a view of ascertaining the amount of electric energy absorbed in the production of one ton of pig-iron.

3. The manufacture of ordinary steel of good quality from the pig manufactured in the preceding experiments.

The different classes of pig-iron were obtained without difficulty, and the

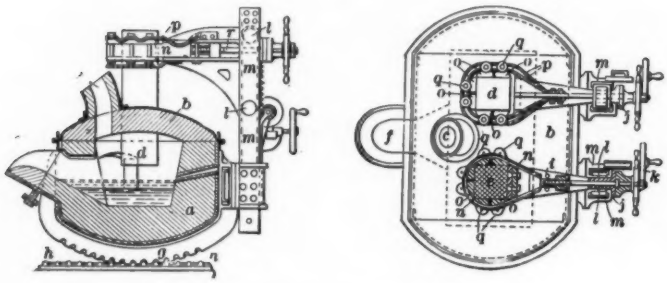


FIG. 4.—HÉROULT'S BESSEMER FURNACE.

furnaces throughout the experiments worked quietly and without the slightest accident, the gases discharging on top in flickering flames, showing that the gas resulting from the reduction of the ore escaped at low pressure. The workmen employed were ordinary Italian labourers without any special training. A number of castings, such as columns, pulleys, gear-wheels, plates, and so forth, were made with the metal drawn directly from the furnace. The castings showed sharp edges, a comparatively smooth surface, and were sound throughout. The electric energy absorbed per ton of pig was found to be ·226 h.p. years.

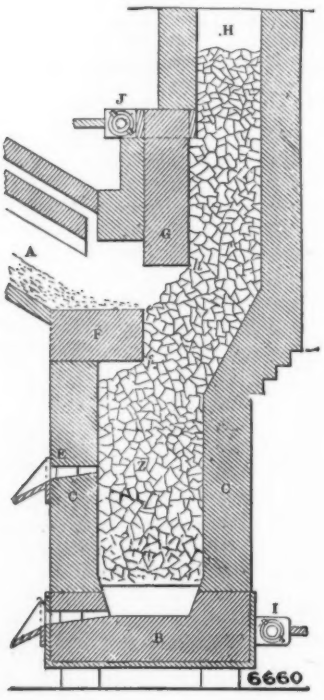


FIG. 5.—HÉROULT'S FURNACE.

The following are the figures which go to make up the approximate cost of producing a ton of pig-iron :—

	£	s.	d.
1. Ore (hematite) metallic iron 55 per cent. 1·842 tons at 6*s.* 2*d.* per ton	0	12	0
2. Coke for reduction, ·33 tons at 29*s.* 2*d.* per ton	0	9	8
3. Consumption of electrodes at 20*s.* 10*d.* per 220 lbs.	0	3	2
4. Lime	0	1	3
5. Electric energy, 0·226 h.p. years, at 41*s.* 8*d.* per e.h p. year ...	0	9	5
6. Labour	0	3	9
7. Different materials	0	0	10
8. General expenses	0	1	8
9. Repairs, maintenance, etc. ...	0	0	10
10. Amortisation (machinery and buildings)	0	2	1
Exclusive of royalty ..	£2	4	8

To satisfy the Commission, Mr. Keller made experiments to illustrate his process of making steel. The details of operation and the figures relating to his experiments are in the hands of Prof. Harbord, the English metallurgist, who accompanied the Commission.

The Héroult Furnace.

This furnace is illustrated in Fig. 4, and, as will be seen, is of the tilting-type

resembling an open hearth furnace. It consists of an iron casing lined with dolomite brick, and is furnished with two carbon electrodes set vertically in the fusion chamber, and passing through water-cooled joints in the cover. The electrodes are adjusted by hand or by a specially constructed regulator. Alternating current of 4,000 amps at 110 volts pressure is used. The furnace was originally employed for the direct reduction of iron ores, but it has been found more suitable for the making of steel from melted scrap. The process is in active operation at La Praz, France, where various classes of steel are made ranging from exceptionally hard steel, selling at £75 12*s.* 6*d.* per ton of 2,000 lbs., down to the tough mild steel at £25 11*s.* 8*d.*

The Canadian Commission referred to above visited these works, and a series of interesting experiments were carried out in their presence in the production of pig from the ore. A simple form of furnace was used of the type shown in Fig. 5, consisting of an iron box of rectangular cross-section, open on top and lined with refractory material. The bottom of the furnace *B*, constituted one terminal of the circuit, a carbon electrode *G* of square cross-section and about 3 ft. in length, constituted the other. Thirty charges of ore were made during the working and 13 taps of metal and slag taken.

The disposition of the electrodes in the Héroult furnace of the tilting type leads to considerable losses of heat through the apertures by which the electrodes enter, although the position of the zone of fusion is more favourable for a transmission of heat to the charge, than in the case of other types, such as the Stassano. The Héroult process is also in operation at Kortfors, Sweden, in the making of ferro-silicon.

The Kjellin Furnace.

This type differs radically from those previously described in that an induction effect is made use of instead of the current being made to directly traverse either the slag or the air space above the charge. Furnaces constructed on this principle have for some time past been at work at Gysinge, Sweden, in the production of superior quality steel, by smelting together charcoal, pig, and scrap. This process corresponds to the crucible steel process, with the advantage, however, that the charge is not exposed to the action of gases generated in the latter case, the absorption of which effects deleteriously the quality of the product.

In the Kjellin furnace, the smelting chamber consists of an annular cavity, *a*, *a*,

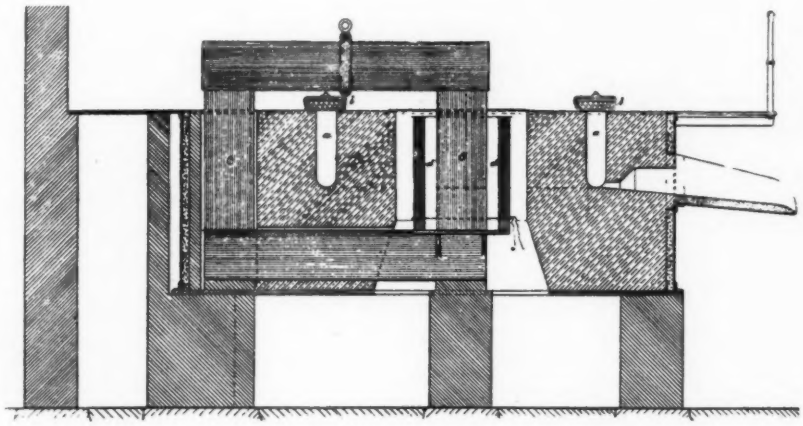


FIG. 6.—THE KJELLIN FURNACE.

FIGS. 7 AND 8.—THE KJELLIN FURNACE IN OPERATION AT GYSINGE.

Fig. 6, coated inside with refractory brickwork, and closed at the top by lids *b*, *b*, which are preferably on the floor level. Through the centre of this ring, one limb, *c*, of a rectangular transformer core passes, the remainder of the core passing round outside the cavity at *c*. The primary winding of the transformer *d*, *d* is placed round that limb of the core which is suspended by the annular chamber. A single-phase alternating current is sent through the primary winding, and induces a flux into the iron core, which, in turn, sets up an enormous current in the material to be melted without the necessity for any electrodes to lead in the current. The value of the induced current depends, of course, on the primary voltage and the number of primary turns.

The first of these furnaces was set up in 1900, and, although producing steel of good quality, the process was slow and expensive, the output being 595 lbs. of steel in 24 hrs., with an expenditure of 78 kw. In 1902 an enlarged furnace was put into operation with more satisfactory results. The capacity of this, as given in a recent communication to the *Elektrotechnische Rundschau*, is 3,960 lbs., of which only about 2,200 lbs. to 2,420 lbs. is tapped at one time, so that the induced circuit is never quite broken. The rate of production is given as 9,050 lbs., or about 4 tons of steel per 24 hrs., with an expenditure of 165 kw. The supply is obtained from a 3,000-volt single-phrase generator, the induced current having an amperage of about 30,000. In the Canadian report above-mentioned, it is stated that the furnace works quietly and regularly, and tapping occurs every six hours. '116 e.h.p. years are required per ton of product, the cost, at the rate of £2 1*s.* 8*d.* per e.h.p. year, working out at 4*s.* 10*d.* per ton of product.

The Gin Furnace.

Closely allied to the Kjillin furnace is the Gin furnace, which is intended to be used in the same way, viz., for making steel from pig-iron. The principal feature of this furnace is that the metal is maintained in a state of fusion in a shallow canal of great length, which is folded on itself as shown in Fig. 9, current being led into it by means of heavy steel

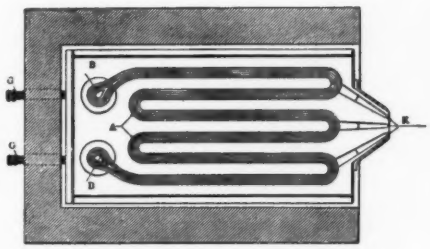


FIG. 9.—THE GIN FURNACE.

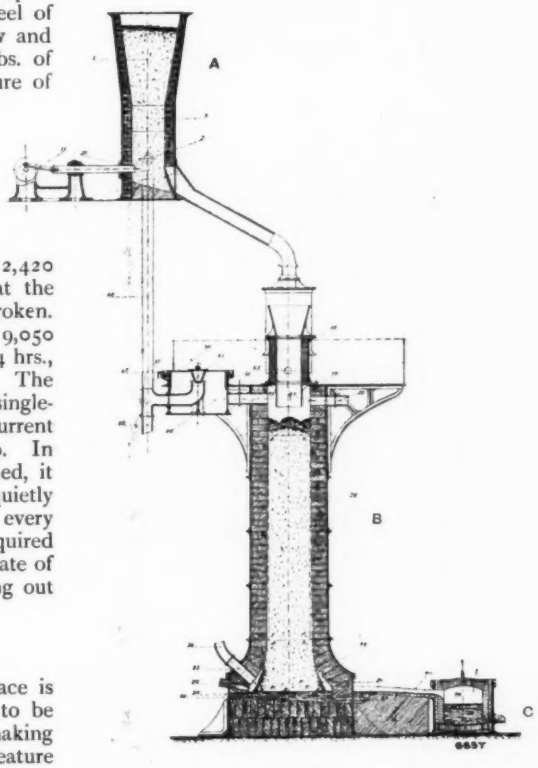


FIG. 10.—THE HARMET FURNACE.

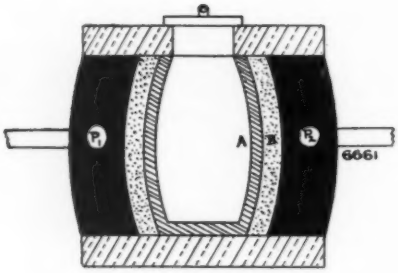


FIG. 11.—THE GIROD FURNACE.

terminals kept cool by a current of water flowing through their interior.

The furnace is tapped simultaneously at the three points shown on the right-hand side of the illustration. The hearth in which the canal is formed consists of some suitable refractory material, and is mounted on wheels running on rails, so that it is capable of being withdrawn from the furnace.

The cost of producing one ton of steel by the Gin process has been estimated at £3 13*s.*, with current at £3 6*s.* 8*d.* per kw. year.

The Harmet Furnace.

This furnace resembles very closely the Keller furnace, and is arranged for making either pig-iron or steel, as may be required. As will be seen from the illustration (Fig. 10), it consists of three portions, one or more of which are used according to the treatment required. *A* is the roasting apparatus, *B* is the reducing furnace, and *C* is the refining furnace, into which the pig is tapped for conversion into steel.

Mr. Harmet states that 3,600 h.p. hours are required by this process to produce one ton of steel from the ore.

The Girod Furnace.

This furnace, which is of the resistance type with a superficial resistance, has been devised by M. Paul Girod of Albertville, Savoie, France. It consists essentially of a crucible *A*, Fig. 11, made of some refractory material, surrounded by a layer of granular or agglomerated graphite *B*, which forms the resistance. Outside the resistance, and placed at regular intervals, are carbon electrodes P_1, P_2 etc., the intervening spaces being built up of refractory brickwork. The cover and base of the crucible are also formed of refractory material, to prevent the escape of heat. The cover is provided with an opening for charging and discharging, the latter operation being effected by tilting the furnace, which is mounted on trunnions for that purpose. Mr. Mc. W. Bennie* states that the furnaces are about 200 h.p. each, and work at a normal pressure of ·25 volt. Very uniform heating is obtained, and bronze, steel, and other metals are easily fused. The temperature is readily adjustable and can be maintained constant at 500 degs. Cent, or raised to 3,500 or 4,000 degs. Cent. when desired. M. Girod has succeeded in fusing with this furnace pure vanadium and ferro-tungsten, which

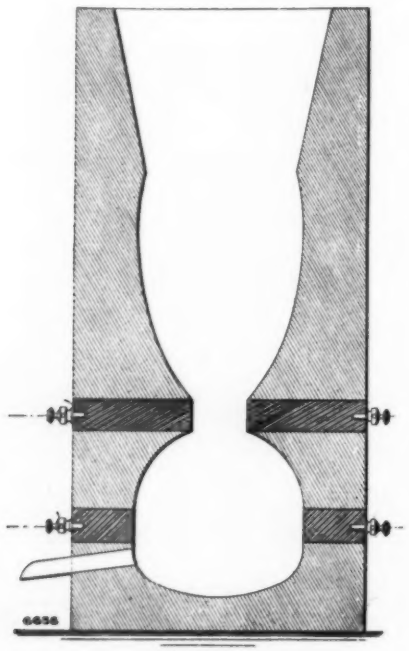


FIG. 12.—THE CONLEY FURNACE.

*Loc. cit.

are fused only with the greatest difficulty. It is stated that 4,400 lbs. of steel per day are being made in the plant at Albertville.

Similar plants are in full activity also at Courtepin, Switzerland, and at Ugine, France.

The Conley Furnace.

This is another type of resistance furnace arranged for the direct production of steel.

It will be seen from Fig. 12 that the furnace is bell-shaped, the narrow end being composed of a material of high electrical resistance, generally a mixture of refractory earth and graphite.

In the latest type of furnace this portion is divided centrally by a wall, the end of which is formed of the same poorly conducting material.

Below the furnace is widened out to form the crucible; also provided with a belt of high resistance, by which the metal decending from the upper part of the furnace can be maintained in a molten condition or be converted into steel. The cost of production by this furnace has been stated to be as low as 843 kw. hrs. per ton, but, in view of the figures ascertained for other systems, it is doubtful if this cost has been demonstrated in practice.

In concluding this review of the various systems proposed, mention may be made of some secondary applications of the electrical system. These are (1) the conversion of pig-iron melted in an ordinary cupola, (2) the pouring of an important casting from several furnaces of less capacity than the total weight of the casting required, and (3) casting hot metal from a battery of crucibles and ensuring the homogeneity of such metal. M. Keller, in his paper before the Iron and Steel Institute, states, in reference to these applications, that for (1) it is only necessary to provide the cupola with a fore-hearth into which the pig is run and to arrange adjustable electrodes and current supply. The necessary ingredients can be introduced in the metal, and steel of good quality can be produced without interrupting the regular working of the cupola. The energy required per ton of steel is only one-twelfth of a kw. year. With regard to (2) this is effected by arranging a casting ladle upon a carriage with means of swinging it in a circle (Fig. 13); it is then charged from the various cupolas and brought underneath the arrangement carrying the electrodes, by lowering which and switching on the current the necessary temperature can be maintained until sufficient metal has been obtained for the castings.

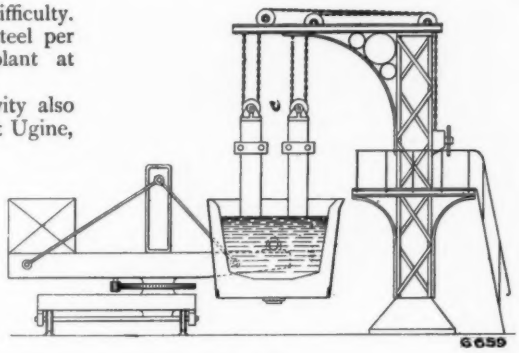


FIG. 13.

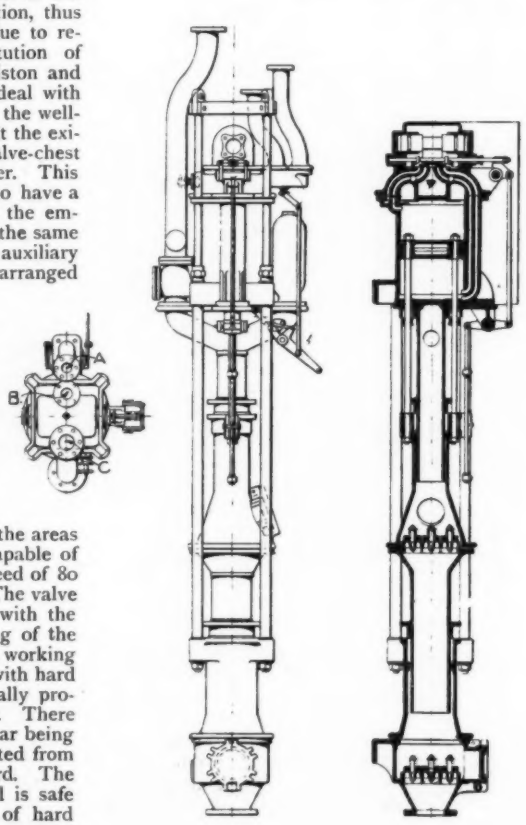
As regards the prospects of the electric furnace in the immediate future, it is not probable, except under very special conditions, that it will replace the blast-furnace or the converter or open-hearth in the production of pig-iron and ordinary steel respectively; but in the case of tool-steel it is certain to find an important application by the utilisation of waste gases for the generation of the necessary current.

As, however, experience in electric smelting accumulates and the absorption of electric energy has, by a more suitable design of furnace, been reduced to a minimum, it may be reasonable to expect that some of the present methods may be displaced in localities where necessary facilities exist for iron and steel production.

ENGINEERING PROGRESS.

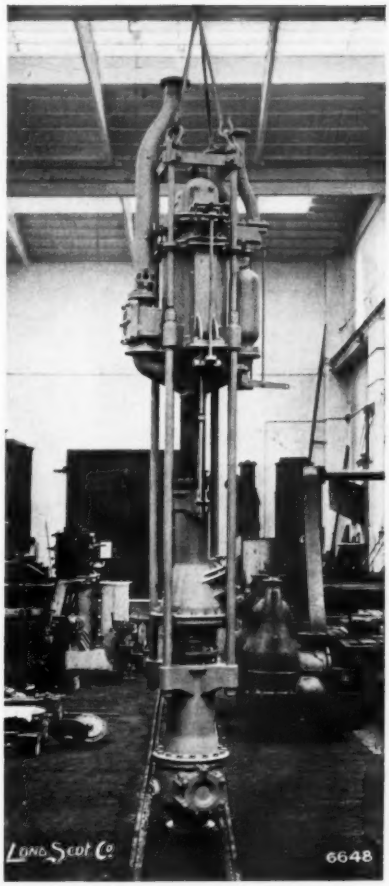
A New Sinking Pump.

An improved pattern of a double-plunger sinking pump has been introduced by the Pulsometer Engineering Co., Ltd., Reading, as a result of many years' experience under widely varying conditions. The pump, as will be seen from the accompanying illustrations, is of the differential plunger type, and has the advantage that the motion of the water is always in the same direction, thus avoiding vibrations and shocks due to reversals. Furthermore, the substitution of outside packed plungers for the piston and piston-rod enables the pump to deal with gritty water. The steam end is of the well-known Deane type, modified to suit the exigencies of sinking, with the valve-chest carried on the top of the cylinder. This position permits the shuttle-valve to have a horizontal movement and obviates the employment of balance weights. For the same reason the rods connecting the auxiliary valve spindles and tappet rod are arranged to balance each other. The steam end is designed to safely withstand 200 lbs. pressure; but the cylinder is sufficiently large for 400 ft. lift with 80 lbs. of steam. For the convenience of operating the pump from above, all the drain-cocks are attached to one lever. The pump illustrated has a steam cylinder 16 ins. diameter by 20 ins. stroke. The diameter of the lower ram is 10 ins., that of the upper ram 7 ins.; the ratio of the areas being, therefore, as 78 : 38. It is capable of lifting 8,000 gals. per hour, at a speed of 80 ft. per min. or 24 double strokes. The valve area is large, and this, combined with the easy water way, renders the working of the pump smooth and regular. All the working parts of the valve-gear are bushed with hard gun-metal, the surfaces being liberally proportioned in order to reduce the wear. There are no internal tappets, the valve-gear being all outside, but is efficiently protected from injury by an easily removable guard. The pump end is substantially built, and is safe up to 600 ft. lift. The valves are of hard rubber, and being of the dead lift type cannot be punched through. Access to the interior is readily obtained by large hand-holes fitted with hinged doors. In order to give an easy flow to the water and to prevent condensation of the steam by the proximity of cold water, the outlet from the upper plunger is carried some little distance below the cylinder bottom. Great attention has been paid to the question of slinging. The steam cylinder is connected



A NEW SINKING PUMP.

with the water-end by four steel columns, which are carried up above the water chest, and after being stayed are fitted with lifting shackles. To enable the pump to be bolted to the side of the well, brackets have also been provided. The rising main, steam and exhaust-pipes are grouped around the slinging chain in such a way that they can all be bound together, the arrangement being such that the rising main balances the steam and exhaust-pipes for all lifts, thus allowing the plant to be hung plumb under all circumstances. The pump is made in four standard sizes, capable of dealing with 2,500, 5,000, 10,000 and 15,000 gals. per hour respectively.



A NEW SINKING PUMP.

An Overhead Track for Foundries.

THE problem of the expeditious carrying of ladles and the rapid pouring of metals is one which does not appear to have received, in the foundries of this country, the attention it deserves. It, however, forms one of the points of economy which is well recognised in American foundries, where the overhead carrying system has been developed to a high degree of perfection. In these circumstances therefore it will be of interest to give a few particulars of an improved method which has been recently introduced by the Wilcox Manufacturing Co., of Aurora, consisting of a system of ladles suspended from roller-bearing carriers which travel on an overhead trolley-track. The details will be gathered from the accompanying illustrations, of which Fig. 1 shows a section of straight and curved carrying track with a two-way switch in connection ; Fig. 3 a view of the conveying track as installed in a large brass foundry; and Fig. 2 a plan of one of the latest systems applicable to a foundry of any size, and which, with modifications, can be used with more than one cupola. The running track is formed from sheet steel by the use of powerful machinery, and has an opening on the lower side through which the pendant, carrying the load, passes. The steel is bent inwards at the opening, thus forming a flat tread about $\frac{3}{4}$ in. wide on which the wheels of the carriers roll. It has been found very advantageous to have this wide horizontal bearing, as wear is thereby reduced and friction diminished. The track is supported by means of forged steel brackets bolted to any kind of overhead structure. All the parts are made of steel. Referring to Fig. 2, the method of operation is as follows : A main track passes in front of the cupola and round the sides, which latter are connected by a series of branch or shunt tracks numbered from one to eleven. Switches connect them to both main tracks. Running parallel to the main track is an overhead travelling-crane which is connected with the main track near the cupola by means of the switch and spur track. The cupola is tapped and metal flows into ladle No. 1, ladle No. 2 catching the flow without stopping off. Ladles Nos. 3, 4 and 5 catch the flow in the same manner. As soon as No. 1 ladle is full, the workman pushes this

FIG. 1.—SECTION OF STRAIGHT AND CURVED CARRYING TRACK.

over the switch on to No. 1 track and begins pouring into the moulds. No. 2 switch is then thrown over, enabling No. 2 ladle to pass on to that track, and so on for all the rest. As soon as No. 1 has finished pouring it is returned to the cupola to receive another load, and is then run on to No. 6 track or any other one needed, thus rendering the pouring one continuous operation. Very heavy work is dealt with by the travelling crane, which is provided with a quick-speed spur-geared hoist enabling the ladle to be raised quickly to any desired height. The ladles being unhooked, the overhead trolley track and carriers are afterwards used for transporting the castings to the cleaning room. The carriers are provided with case-hardened steel roller bearings which permit the carriers to run very easily. It is stated that one man can move 500 lbs. of metal quite easily with this system.

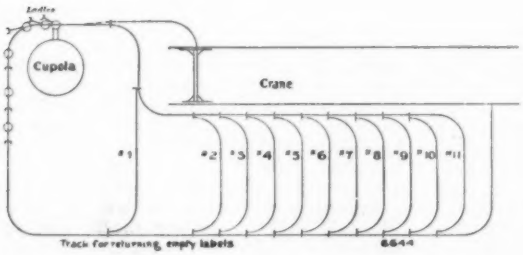


FIG. 2.—ARRANGEMENT OF OVERHEAD TRACK FOR FOUNDRIES.

A New Bench Vice.

THE illustrations on page 350 refer to a new and simple bench vice about to be placed on the market by Mr. Charles Taylor, of Birmingham, whose name is well known in connection with a similar tool. That about to be described, however represents an improvement on its predecessor in the simplicity of its construction and facility of manipulation. It will be seen from Fig. 1, which shows the vice separated into its components, that it consists of but five parts, of which *A* is the fixed jaw and body combined in one casting, *B* the usual sliding jaw, *C* the screw, *D* the half-nut, which is customarily employed in this type of vice; *E* a sleeve which actuates the half-nut, and replaces the usual mechanism by means of a trigger, springs, etc.

The half-nut *D* is engaged with the screw *C* automatically by a movement of about one-twelfth of a turn, the whole work of gripping, releasing, engaging, and disengaging the mechanism being done by one hand, held in one position at the end of the lever, a very obvious improvement.

Fig. 2 shows the position of the hand during the whole of the operations.

Fig. 3 is a sectional elevation, in which the half-nut is shown in engagement with the screw. It will be clear that, upon turning the screw in an anti-clockwise direction, immediately the gripping pressure is relaxed, the nut will fall out of engagement, and the jaw *B* will then be free to slide.

The work being placed between the jaws, the jaw is pushed up to the work, and the lever is rotated exactly as though the vice were a continuous screw vice. The first portion of the turn raises the nut into full mesh with the screw by means of the sleeve *E*, which has a flexible

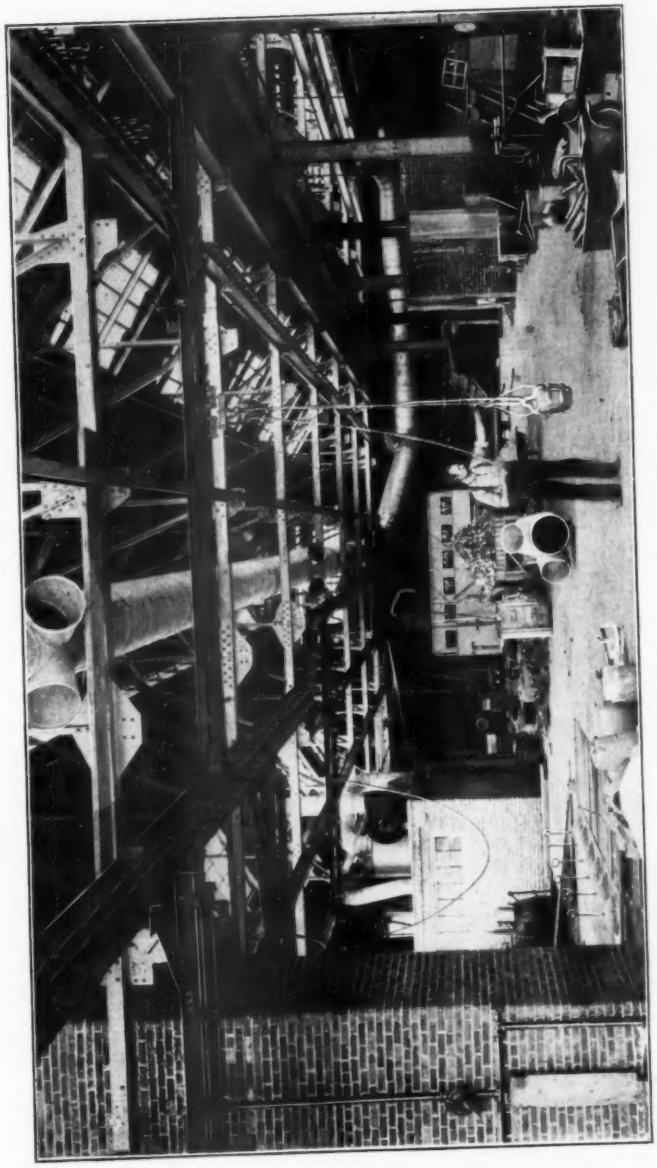
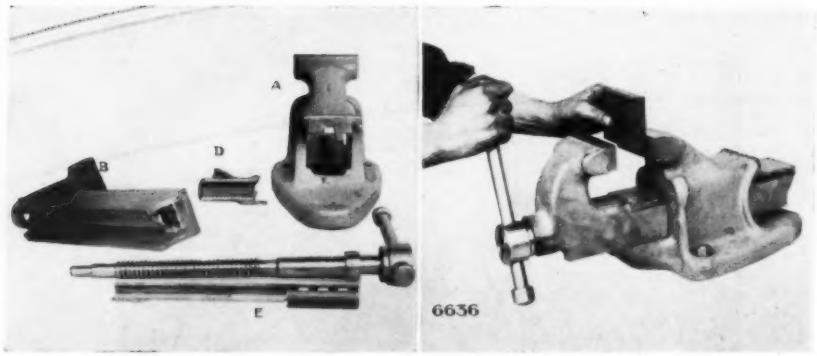


FIG. 3.—INTERIOR OF BRASS FOUNDRY, SHOWING OVERHEAD CARRYING TRACK.



FIGS. 1 AND 2.—NEW BENCH VICE.

grip upon the screw, and turns with it until held by some positive stop, the projection of the lip $E1$ (see end view) fouling the corresponding lip $D1$ of the nut.

It will be noticed that the nut is guided in ways $A1$ at the base of the fixed jaw, the whole of the end strain being borne by the abutment $A2$.

While lifting, the screw and nut may make contact at the tips of the threads, and the nut be prevented from rising further by eason of the binding strain arising from the forward motion of the screw thread, and then the tips of the thread are apt to break off. This is a point of failing in many vices, but is completely obviated in the new type in the following manner. A slight clearance is permitted in the upper way $A1$, to allow the nut to fall away from the abutment $A2$, by reason of its unbalanced position, and by the legs $D2$ resting upon the part $A3$ of the body. The angular disposition of the ways also tends to the same end, the nut advancing while rising, so minimising the effect of the advancement of the thread while the screw is turning. This feature, with a thread slightly undercut on its acting face, also tends to cause a clinging together of the screw and

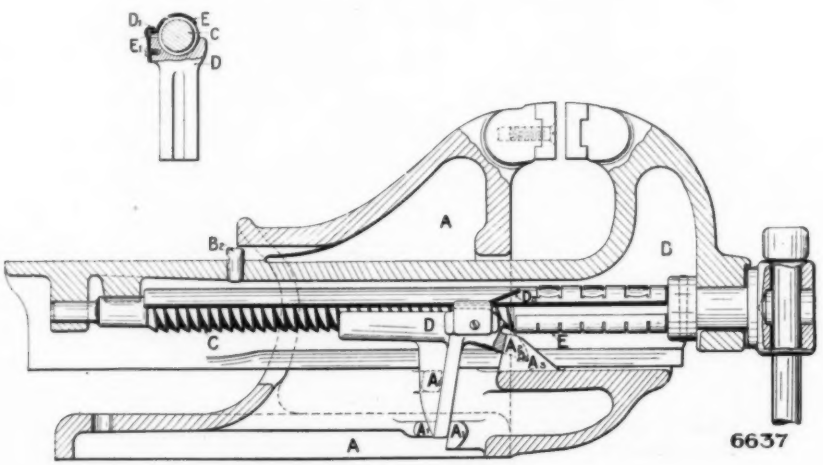
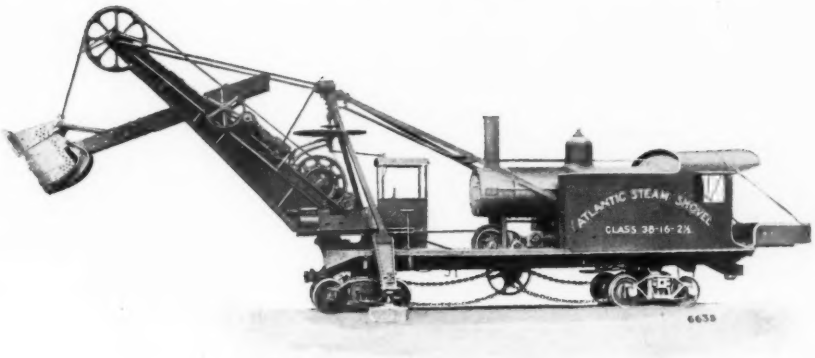


FIG. 3.—NEW BENCH VICE.



STEAM NAVVY OF NEW DESIGN.

nut, making it impossible that they should separate under blows or vibration.

A few points of minor importance, yet making for general efficiency, may be mentioned—viz., the jaw-plates are removable to facilitate renewal when worn, and are tenoned on in order that no strain will be borne by the screws; the sliding jaw is readily removed for oiling by removing the stop *B2*. Finally, owing to the peculiar construction of the vice, the screw is higher, and thus nearer to its work, than in other vices of the same type.

Steam Navvy of New Design.

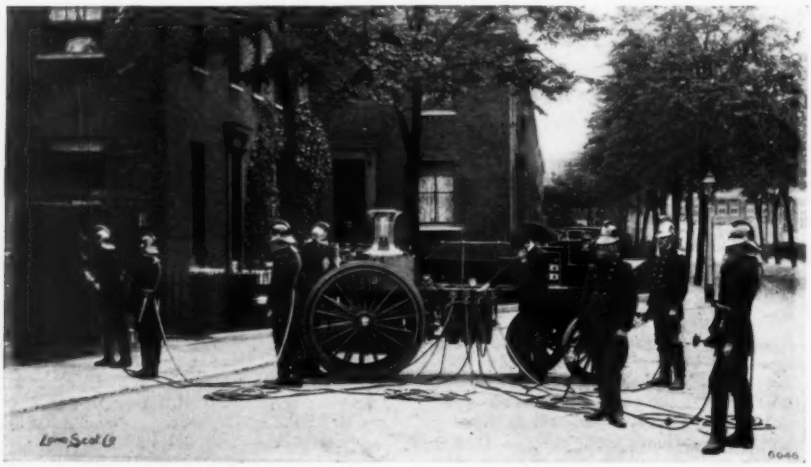
PRACTICE in the design and construction of steam navvies has up to the present followed well-defined lines, and any development that has taken place in recent years has been not so much in the way of departure from standard design as in increase of size and weight. Ten years ago the railway steam navvy weighed about 35 tons, and carried a dipper of 1½ cub. yds. capacity; now there are in use some weighing 90 tons, carrying a dipper of 5 cub. yds. capacity. Size and weight, however, do not necessarily make for the highest efficiency, and if there is one type of apparatus more than another in which excessive weight is a disadvantage it is the steam navvy. It will at once be seen from an inspection of the illustration that several important changes have been made in the machine under notice, the chief being the substitution of a wire rope for the chain actuating the dipper hoist; hoisting by direct pull instead of by block and tackle; placing the hoisting engines directly on the turn-table at the base of the boom; attaching the hoist rope directly to the dipper; and finally, the adoption of a locomotive type boiler, cab, and water tank. By these features the makers claim that a greatly improved efficiency has been attained, the shovel exerting no less than 40 per cent. of the theoretical engine power at the teeth of the bucket.

In the boom there is a departure from the usual practice by making it with a straight taper, deepest at the inner end. The upper members of the boom are steel channels set vertically, and the lower members channels set horizontally, while the web is a solid steel plate. The turn-table is built solid with the boom, and both turn-table and boom are separate from the revolving collar on the base. This method of construction enables a shorter boom being employed to accomplish the same height and reach as other machines. The hoisting is done by direct wire-rope with but one sheave, instead of by chain with from 5 to 7 sheaves as is usual. The difficulty hitherto in the way of applying a wire rope hoist to steam navvies has been in guiding the rope from the drum to the dipper. In this instance the hoisting machinery is mounted directly on the boom, so that no guide sheaves are necessary. A pair of engines, with drum gearing, are fixed at the base of the boom, and can pull the required amount on the dipper at a speed of 5 or 6 loads per minute. The entire frame of the engines is of cast steel in one piece, and forms the foot of the boom and

centre of the turn-table as well. The load at the base of the boom due to weight of the parts is not more than four tons, or 10 per cent. of the load due to working stress. A most important function of this weight is to balance the boom and loaded dipper when in side position, the weight at the base of the boom being more effective for this purpose than weight in the middle of the car. The hoisting drum is of large diameter and grooved for steel wire rope. There are two parallel ropes each bearing half the load equalised round a small sheave at the dipper. The two ends of the rope are secured by clips at the drum. In the construction of the dipper, the bail and sheave have been discarded, and the double hoisting rope attached directly to the back of the dipper in such a way that the lines of force meet in a point situated in the plane of the resistance or in line with the strain applied to the teeth. By the old method it would require a boom 6 ft. longer to lift the dipper to the same height. The thrusting engines which feed the shovel to its work are of new design, with no parts exposed which could be injured by flying fragments from blasting. The swinging engines are independent, and duplicates of those on the boom for thrusting. Propelling motion is performed by these through a cross shaft geared by chains to the forward and rear axles. The **A** frame is formed of solid steel bars having a cast-steel head of new design so arranged that the three strains intersect in a point. The **A** frame can be lowered when required for transportation to 15 ft. above the rails. Pin connections at the feet of the **A** frame permit of this movement, and the back guys are shifted forward to a connection provided for the purpose. The raising and lowering of the **A** frame is done by power from the swinging engine. This shovel was made from the design of Mr. A. W. Robinson, M.Am.Soc.C.E., by the Atlantic Equipment Co., of New York, and is in use on the New York Central and Hudson River Railroad. Another of the same design is in the exhibit of the American Locomotive Co. at the St. Louis Exhibition.

Developments in Fire Apparatus.

THE Corporations of Liverpool and Manchester are to the fore in the adoption of up-to-date Fire Brigade equipment. The latter Corporation has just put into service an auxiliary apparatus, consisting of a steam fire-engine, with certain additions, which will greatly facilitate the work of the brigade in tackling a smoky fire, by providing light, air, and means of communication between the men and the officer in charge. It has been constructed by Messrs. Merryweather & Sons, of Green-



AUXILIARY FIRE-ENGINE FITTED WITH TELEPHONIC AND ELECTRIC LIGHTING APPLIANCES.

MOTOR-DRIVEN LIQUID-FUEL FIRE-ENGINE FOR LIVERPOOL.

wich, and is illustrated on page 352. The additions consist of helmets, fitted with telephones, and an air-draught arrangement and incandescent lamps, carried by the firemen and supplied by current generated on the engine. The latter has a quick, steam-raising water-tube boiler, supplying steam to a single-cylinder vertical engine, suspended between the side frames. Alongside the steam cylinder is fixed a single-barrel air-pump, driven by a coupling and gear from the crank-shaft, and so arranged that it can be thrown out of action when desired. The air-pump supplies four valves fixed on the side frame, quick-hitching couplings being fitted to these valves for hose connection to specially-designed smoke-helmets. Over the fore carriage is placed a dynamo, belt-driven from the fly-wheel of the engine, supplying eight 32-c.p. incandescent lamps. Six reels are fitted, holding 200 ft. of flexible insulated cable for the lamp circuit. In the centre of the machine a large cage is fitted, carrying six 60-ft. lengths of flexible metallic air hose, in coils. In front, under the driver's foot-board, is a receptacle containing the telephone batteries and also the smoke-helmets. Each helmet is of leather, with a mask extending over the shoulders, the front under the peak being left open. The air-hose coupling is at the back, and the draught is distributed round the wearer's head in front, so as to keep the eyes and nose clear of smoke. Inside the mask are also fitted a telephone receiver and transmitter, wires being led through the air-valves, from which they are carried to a switchboard, enabling the officer in charge to communicate with his men working in darkness or smoke at a distance.

The novel features embodied in the fire-engine forming the subject of the second illustration are that it is steam-motor-driven and the boiler is designed to use liquid fuel. Kermode's system of firing has been adopted, in which steam is utilised to heat and pulverise the oil-fuel, driving it into the fire-box together with a stream of induced air, through a single burner 11 ins. in length and 9½ lbs. in weight. The oil enters the burner centrally, and has a whirling motion imparted to it by the stem of the oil-valve which forms a spiral guide. The induced air has also a whirling motion imparted to it by a similar apparatus. The range of adjustment for the steam orifice is large, and the flame can be turned down until it suffices for merely keeping the boiler working. Steam pressure may be varied by means of a hand-wheel valve between 16 lbs. and 33 lbs. The oil flows by gravity to the burner, although in working the latter can lift it to a height of 2 ft. if necessary.

The engine has given complete satisfaction

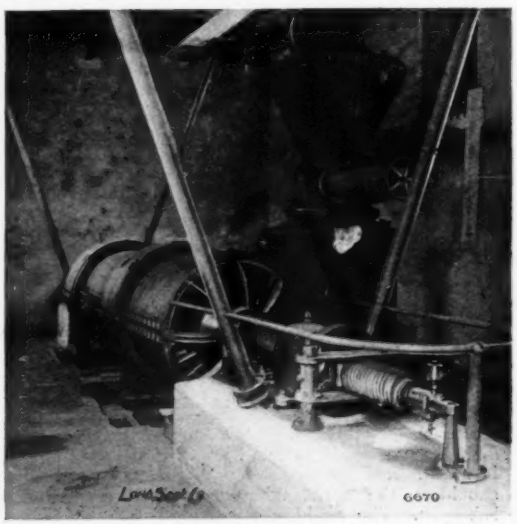
during the time it has been in service, a speed of 20 mls. per hr. being readily maintained. Further, the combustion being complete no sparks or smoke are emitted, nor is any burning fuel dropped during the journey. When standing in the station steam is maintained at 80 lbs. pressure by a gas grill inside the fire-box. On this being withdrawn and the oil turned on the engine is at once ready to start. This engine was built for the Liverpool Fire Brigade, also by Messrs. Merryweather, the oil-fuel apparatus being supplied by Kermode's Liquid Fuel System, Dale Street, Liverpool.

The Stolze Gas Turbine.

A GOOD deal of attention has been recently devoted to the question of the Gas Turbine, as may be gathered from the fact that two very important papers have recently been read in Germany and this country, abstracts of which will be found in another portion of this issue. It is extremely doubtful, however, whether anything but the roughest experimental work has hitherto been done in connection with this form of prime mover, there being a conspicuous absence of data in the proceedings of learned societies or in the technical press. We are, however, enabled to give some particulars with an illustration of a gas turbine devised by Dr. Stolze, of Charlottenburg, which is attracting much attention at the present moment in German engineering circles. It appears that patents were applied for by Dr. Stolze as far back as 1873, but it was not until 1897 that they were granted. An interesting feature of this specification of more than thirty years ago is that it describes fully the application of the multiple step principle for diminishing speeds, an application which plays so important a part in steam turbine construction to-day. The following are the leading particulars of this engine :—

To a common axle are mounted two turbines of different design, one of which serves as a rotary air pump, the other being the motor portion driving the shaft by means of hot air and gases. Both turbines are constructed with rows of guide vanes fixed to the engine casing, with corresponding rows of running vanes of similar design fixed to a common conical rotary body, which turns with the axle. The air entering the compressor is passed thereby under pressure through a preheater heated by exhaust gases, part of the air passing to a combustion chamber, the remainder being conveyed to a producer gasefying there a convenient fuel. The gas thus formed passes into the combustion chamber, where it is burned in suitable burners to carbon dioxide and water vapour. These gases pass to the motor portion of the turbine system, where they do work by expansion in traversing the various steps. The process is thus strictly analogous to the cycle of all combustion engines, consisting of air-induction followed by a subsequent compression, the mixing with fuel, combustion, expansion, and discharge. In most of the gas motors now being built, the mixing, it is true, takes place before compression, and the combustion under increasing pressure; this, however, is no essential difference. The Diesel motor resembles very closely the gas turbine in its working cycle.

Instead of producer gas any other kind of gas can evidently be used, as well as carburated air or benzine, alcohol, or petrol vapours. We understand that a large size engine of an effective output of 200 b.h.p. is in course of construction, with which the inventor anticipates obtaining some very satisfactory results.



THE STOLZE GAS TURBINE.

BOOK REVIEWS.

Automatic Surveying Instruments and their Practical Uses on Land and Water.—By Thos. Ferguson, Member of the Shanghai Society of Engineers and Architects. With an introduction by E. Hammer, Ph.D., Professor of Geodesy at the Royal Technical High School of Stuttgart. (London: John Bale, Sons, & Danielsson, Ltd. 1904).

Those who may be engaged in surveying operations in foreign countries, will find information of considerable practical value in this little book, which is devoted to a detailed description of three separate types of automatic surveying instruments. Few appliances intended for automatically tracing a plan of a road over which they are transported, or for automatically arriving at the longitudinal section of the line over which they are carried, have attained any material success, either because they are not sufficiently reliable, or because they are too complicated, and therefore too expensive and apt to get out of order.

The "Pedograph," invented by the author, is an instrument larger in size than the ordinary pedometer, and is evidently far more accurate. Moreover, it contains a frame to which a sheet of drawing paper can be affixed, and on this paper a facsimile is automatically traced of the path followed. The next instrument described is an automatic route-tracer, called the "Cyclograph," which is intended for attachment to a wheeled vehicle, preferably to a bicycle. The instrument can be used on any surveys where a bicycle may be ridden or pushed. When the machine can be ridden, it is quite possible to obtain automatic records of the route followed at the rate of 8 mls. or 9 mls. an hr. on passable roads, or at a walking pace in country where the machine has to be led. Like the pedograph, this instrument also traces a facsimile of the path followed upon a sheet of paper. The "Hodograph," designed by the author as an aid in mapping some extremely intricate systems of waterways in China, is an instrument intended to be placed upon a boat, and operated by means of a propeller towed behind like a ship's log. Although records taken on water cannot be so accurate as those furnished by a road instrument like the Cyclograph, they are sufficiently close for approximate surveys, and there is no doubt that the hodograph should be extremely useful under many circumstances.

The book contains detail diagrams of the various appliances described, full directions for use, and plates giving practical examples of surveys made by the author.

Electrical Engineering Measuring Instruments for Commercial and Laboratory Purposes.—By G. D. Aspinall Parr, M.I.E.E., A.M.I.Mech.E., Head of the Electrical Engineering Department, Yorkshire College, Victoria University. With 370 illustrations. (London: Blackie & Son, Ltd.) Price 9s. net.

Too little attention has been devoted by writers on electrical subjects to measuring instruments, and the present volume therefore deserves a welcome, the heartiness of which should be considerably increased by the admirable manner in which the appliances are described and illustrated. Practically every form of instrument used in this country at the present day is noticed, as also are many types used on the Continent. The author has classified the different instruments by considering them in chapters where those types working on the same principles are discussed. That this arrangement is convenient will be seen from the following brief summary of the contents. After a chapter occupied with general considerations, we have in succession others upon moving-needle and moving-coil electro-magnetic instruments; hot-wire and electro-static instruments; electro-magnetic watt-meters; recording ammeters, voltmeters, and watt-meters; miscellaneous instruments; and electricity supply meters. It will be seen, therefore, that due attention is paid to the four branches of measurement required in everyday practice — the measurement of current, pressure, power, and energy. The distinction between power and energy, as the author remarks, should be clearly understood, so that the "recording watt-meter" may not be confused with the "integrating watt-hour meter." The relation of one to the other may be remembered by the equation, Energy = Power × Time. Each chapter commences with a few general notes and a

statement of the advantages and disadvantages of different types of instruments, but without entering upon invidious comparisons between the appliances of individual makers. In a brief appendix the reader is referred to text-books where he may find descriptions of a few special instruments outside the scope of the present treatise. The volume is admirably produced, and we have confidence in saying that its success from the standpoint of the publisher will be as complete as that already attained by the author.

Experiments on the Flexure of Beams. Resulting in the Discovery of New Laws of Failure by Buckling.—By Albert E. Guy.—(New York : D. Van Nostrand Co. ; London : Crosby Lockwood & Son, 1903.) Price 9*s.* net.

This treatise presents an entirely novel method of considering the flexure of beams. In most text-books, the subject is dealt with in a manner that is almost stereotyped, and ordinary formulas entirely fail to recognise some distinctive characteristics of beams under flexure. The lateral resistance of beams in particular has received very little attention, and it is to this feature that Mr. Guy chiefly devotes himself. Many engineers have observed the analogy of the failure of a beam by buckling to the failure of a long column, but no serious attempt has previously been made to connect the two modes of failure in a definite and intelligible manner. After several series of experiments, conducted with considerable care, the author has apparently succeeded in demonstrating the fact that Euler's well-known formula for columns is also applicable to the failure of beams. The investigation described in this work deserves the most careful examination, and the recorded results appear to prove the accuracy of the new theory propounded by the author. He has deduced a series of formulas that should be of service to all who are concerned with the design of beams for various purposes, and one of the most useful rules is that by which may be determined the limit within which a beam will fail in the ordinary manner, and beyond which it will fail by buckling. Henceforward, the designer will have at his disposal a simple method of ascertaining the proportions necessary to guard against failure by lateral collapse, a feature that text-books ordinarily dismiss with vague generalities. Although the work does not profess to be a complete treatise on the flexure of beams, it contains matter of the utmost importance and should be studied by every structural engineer.

The Cyanide Process of Gold Extraction.—By J. Park, Professor of Mining, and Director of Otago University School of Mines. Third edition. (London : C. Griffin & Co.) 7*s.* 6*d.*

Students of metallurgy and mining or cyanide operators have presented within the limits of 187 pages an exceedingly clear and concise account of the cyanide process of gold extraction. The opening chapters, i. to iv., may be regarded as introductory, giving brief descriptions of the McArthur-Forrest process and its limitations, an outline of the chemistry involved, laboratory experiments, and methods for the control, testing, and analysis of solutions. The fifth chapter, in which appliances and plant are described, forms with its illustrations one of the most valuable of the book, a value further enhanced by a series of approximate costs of plants of various capacities in Australia and New Zealand. Succeeding portions deal with the extraction, treatment of slimes and concentrates, leaching, and precipitation. Some 49 pages are devoted to a study of the application of the cyanide process in different countries, and are followed by a description of the Siemens-Halske method of electrical precipitations and other modifications. In a work of this character, the concluding chapter on antidotes for cyanide poisoning appears very appropriate, and the author's advice as to the provision of an accessible "remedy cabinet" is worthy of adoption in all cyanide plants.

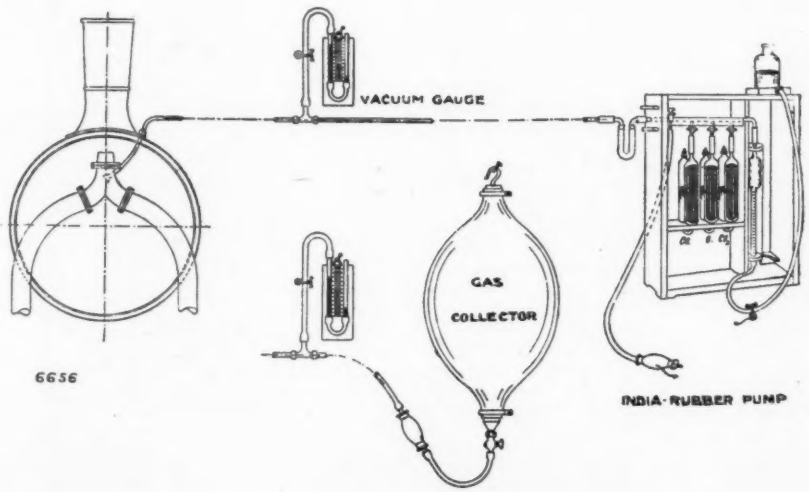
Engine Tests and Boiler Efficiencies.—By J. Buchetti, Paris. (Translated and edited from the 3rd Edition by Alexander Russell, M. I. E. E., etc.) (Westminster : Archibald Constable & Co., Ltd., 1903). 10*s.* 6*d.* net.

In the third edition of his standard work, "Guide pour l'essai des moteurs," M. Buchetti has made considerable additions to nearly every chapter, especially in those relating to the theory and practical working of indicators and similar apparatus. The English edition by Mr. Russell, now published, should be useful to British and American engineers for the purpose of comparing the best Continental practice with that adopted in their own countries, and the chapter by Mr. C. A. Parsons on "Steam Turbines" is a welcome addition to the work of M. Buchetti. The work of translation has been admirably performed by Mr. Russell, who has in every case converted measures and tables into British units, and adapted the formulæ into British measure. A large number of drawings and diagrams is included, and the work is very clearly printed and well got up.

RAILWAY NOTES.

Smoke Gas Analysis and Locomotive Evaporation Tests.

THE absence of any reliable data concerning the amount of heat lost in the working of the locomotive, recently led the Breslau Royal Railway Department to organise a series of trials with a view of determining the composition of the smoke gases escaping through the chimney, and to ascertain some definite information respecting the vaporisation capacity of several types of locomotives. The results of these trials are set forth in detail in *Glaser's Annalen* of Sept. 1st and 15th. In making the analysis of the smoke gases, the well-known Orsat-Fischer apparatus was used, comprising three absorption vessels for carbonic oxide, oxygen, and carbon mon-oxide respectively, which three components of the smoke gases are read direct in volume per cent., the nitrogen being found by calculation. The arrangement is represented diagramatically in the accompanying illustration. The pipes consisted of copper and indiarubber, and terminated in the centre of the smoke-box between the blast-pipe and the front tube plate. The gas samples were pumped into the apparatus by means of an indiarubber pump. The vaporisation tests were carried out on standing locomotives in which the valves had been removed, the quantity of steam issuing from the exhaust being regulated until the desired steam consumption was obtained. By observing the degree of air exhaustion in the smoke-box the steam consumption was easily kept constant. The following were the conclusions reached as a result of the experiments. (1.) The heat escaping in the smoke gases is 20 to 23 per cent. of the total heat value of the coal. (2.) The loss by the combustible components found in the residue varies according to the design of the locomotive from 5 to 11 per cent. of the total heat value of the coal. (3.) The loss by radiation, smoke and spark production was about 5 per cent. (4.) The efficiency of the boiler therefore varied from 60 to 70 per cent. (5.) The co-efficient of vaporisation is 6 : 8, no considerable quantity of water being carried from the boiler by the steam. (6.) The average temperature in the smoke-box was from 330 to 380 degs. Cent. (7.) The mean temperature of combustion in the fire-box was found to be 1485 degs. (8.) The mean specific heat of the smoke gases of



APPARATUS FOR TESTING LOCOMOTIVE SMOKE-GASES.

average composition reduced to 0 degs. with the barometer at 160 mm. is $c_p = 0{\cdot}324$ for a smoke-box temperature ranging between 350 and 400 degs., and $c_p = 0{\cdot}35$ for the fire-box and fire-tube temperatures. (9.) The mean air exhaustion in the fire-box was 50 to 60 mm. water column. (10.) The smoke gases, with the locomotive in full running and 350 degs. temperature in the smoke-box, were found to contain an average of 11 per cent. carbon di-oxide and 0·6 per cent. carbon mon-oxide. (11.) From one kilogram of coal 11 to 12 cub. m. of smoke gas were obtained at 0 degs. with the barometer at 760 mm. (12.) The design of the chimney and blast-pipe should be different in locomotives using super-heated steam from those using saturated steam. (13.) One-third of the smoke gases were found to pass through the superheater of the locomotive experimented with.

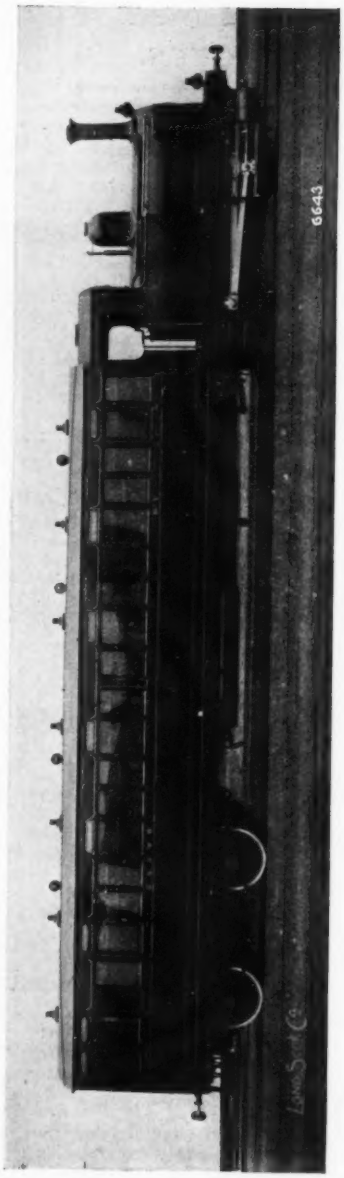
Steam Motor Carriage for the Glasgow and South-Western Railway.

IN order to test the relative economy of self-contained railway cars for the conduct of local traffic, the Glasgow and South-Western Railway have recently built at their Kilmarnock Works a special steam motor carriage, from the designs of Mr. Manson, the Locomotive and Carriage Superintendent.

The car, which is 60 ft. 8 ins. long over the buffers, is divided into three passenger compartments and a special compartment for the steam motor; the one at the rear is a guard's compartment, the two adjoining being reserved for passengers. These three compartments are only separated from each other by a sliding door, while at the same time each compartment has a separate door, by which passengers can enter or leave the car at the station platforms.

At the guard's compartment steps are provided to enable passengers to enter from the road level, and these are so arranged that they can be brought into use by actuating a lever in the guard's compartment.

The car is seated to accommodate 50 passengers of one class, the seats being so arranged that there is a free passage from end to end of the car. The seats are upholstered in plaited Rattan cane, the floor is covered with inlaid linoleum, the roof being panelled with alhambrine, finished white and picked out in gold; the carriage is lighted by Pintsch's oil-gas, each passenger compartment being fitted with parcel nets above the quarter lights.



STEAM MOTOR CARRIAGE, GLASGOW AND SOUTH-WESTERN RAILWAY.

The underframe, which is of steel, is carried on two suspension link bogies, the bogie at the rear being of the standard type used for the ordinary stock.

The leading bogie is virtually a small outside cylinder locomotive, complete in itself, and yoked to the car in such a way that it can very readily be attached or detached.

Electrical communication is provided for the convenience of the guard and driver.

Hand and vacuum brakes, which can be operated from either end of the vehicle, are fitted to each bogie, and in addition the steam-whistle can be sounded from the guard's compartment.

The boiler is of the locomotive type, with copper firebox and brass tubes, the boiler containing 138 tubes 1⅞ ins. external diameter.

The cylinders of the motor are fixed horizontally on the frame of the bogie; they drive on to the trailing pair of wheels, which are coupled to the leading pair, and the slide valves, which are on the top of the cylinders, are actuated through rocking shafts by the company's standard type of link motion and eccentrics.

Externally the car is finished throughout in crimson-lake colour, relieved with gold lines, in the same way as the standard stock of the Glasgow and South-Western Railway.

The principal dimensions are :—

Length over buffers	...	...	60 ft. 8 ins.
,, ,, headstocks	...	...	57 ft. 2 ins.
,, of car body	...	...	41 ft.
Distance, centre to centre of bogies		..	39 ft. 4 ins.
Wheel base of bogies	...	...	8 ft.
Diameter of wheels	...	...	3 ft. 6 ins.
Cylinders ...	...	..	9 ins. × 15 ins.
Boiler. Firegrate area		...	8 sq. ft.
Heating surface (firebox) ...	40 sq. ft.		
Heating surface (tubes) ...	400 sq. ft.		
Total	440		

Water tank (carried under the car) 500 gallons.
Fuel capacity 15 cwts.

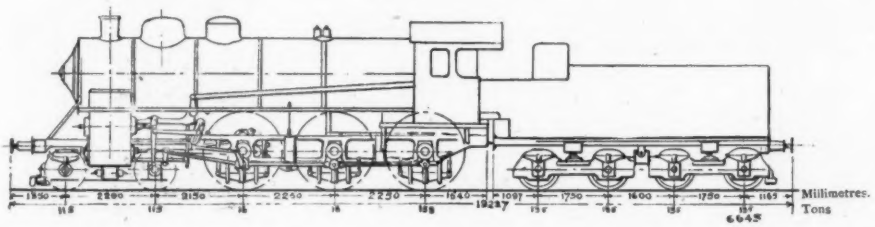
This motor carriage was built in the company's workshops at Kilmarnock for the passenger traffic on the Cairn Valley Line, but until the railway is opened the carriage is being used on the Mauchline and Catrine branch. The results of the working of this steam carriage are to be carefully noted, and if they prove to be as satisfactory as anticipated, further advantage will be taken of this method on other parts of the system.

New Bavarian 4-Cylinder Locomotives.

THE Bavarian railways have just introduced some powerful express locomotives, which are among the largest yet constructed in Europe, and embody a number of important constructive changes of special interest to engineers.

We illustrate one of these engines, which are designed with that harmony of form which has for years obtained so much pre-eminence for English locomotives abroad. Excepting for the sand-box on top of the boiler, no English locomotive designer could have arranged a locomotive with more symmetry of general lines. But he would scarcely have introduced the Walschaert's valve-gear, which is employed for all modern locomotives excepting in England and America. With the Heusinger and Walschaerts' gears all the phases of the distribution can be mathematically determined in advance, while their distribution of the steam is yet better than the "Stephenson"; and, mechanically, they are more practical and, as a consequence, effectively simpler.

Another particular is the introduction here of bar-frames. The adoption of this feature will now enable American engineers to claim that every notable feature of the American engine has at last entered European practice; the four-wheel pilot truck or bogie, the swing-truck bogie cradle, the cylindrical smoke-box and tube-plate, the "extended smoke-arch," the wide-type fire-box, and from time to time, as more adhesion is required, the grouping of the coupled wheels. This is undeniable, and in return for so many good things it only remains for American engineers to take from Europe some ideas in the form of the modern oblique-arm crank axle and the valve-gears of Walschaerts or Heusinger. For, as arranged in this new locomotive, a four-cylinder engine, with one pair of cylinders located inside



4-6-0 TYPE EXPRESS LOCOMOTIVE, BAVARIAN STATE RAILWAY

of the bar-frames, makes a highly practical combination.

No track-pits are required for attending or over-hauling the inside engines. All the big-ends of the connecting-rods are plainly visible in nearly all positions of the cranks and can be readily observed from the high-running board while the engine is in motion, as all the pistons drive upon one and the same crank-axle. With this system, now adopted for the newest locomotives in all countries outside of France (similarly in fact to the newest London and North Western Railway 4-cylinder compounds), the necessity of deep tie-braces or box-stretchers between the frames, as in the old Webb and De Glehn systems, is avoided at the level of the outer pair of cylinders.

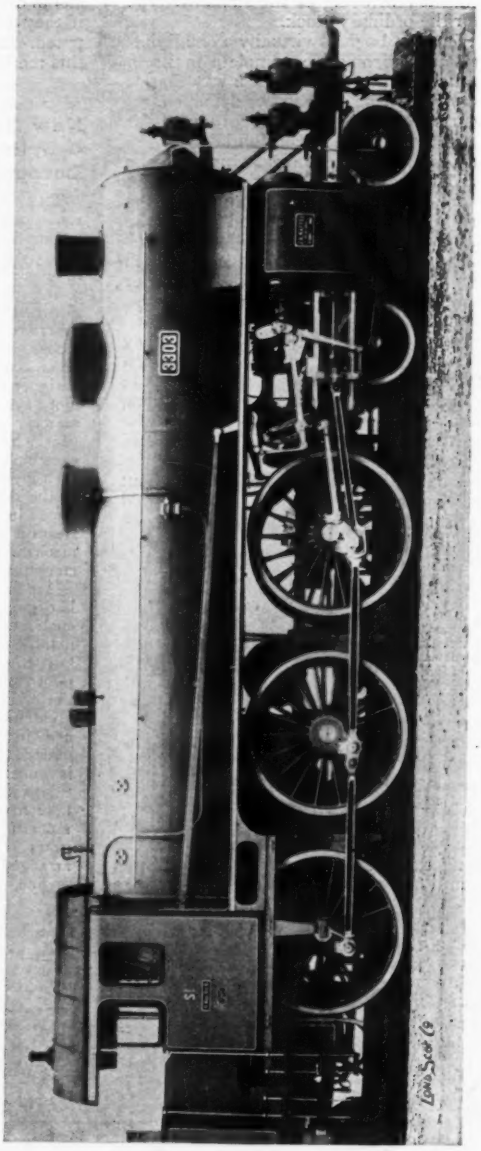
The relative merits of the two systems are now being definitely decided by the adoption of the simplest form, *i.e.*, where all the cylinders are bolted together at the smoke-box end as in the most recent Vauclain compounds.

Apart from objections due to inherent dislike of changing established methods of manufacture, and the costs thereby involved, there are real advantages in the use of bar-frames not only for the greater visibility of machinery placed between them, but also for the fact that they permit of a deeper fire-box.

Already in Austria the inconvenience of the plate-frames has necessitated a sort of compromise with bar-frames, this occurring where the deep plate-frames have been cut away to such an extent to allow room for a very deep box, so that it has been necessary to rivet bars of rectangular section to the plates in order to reinforce them sufficiently.

With high six-coupled driving-wheels various expedients or else bar-frames must always be resorted to to get in a box of maximum width and depth; with the sole exception however of adopting, entire, the "Adriatic" arrangement with the boiler reversed on its frames, when it is possible to build fire-boxes of any size allowable by the construction gauge, *i.e.* as large as a railway coach, entirely without regard to dimensions of the coupled wheels.

In addition, bar-frames, in spite of the large number of deep holes bored through them, possess constructional advantages in the facility with which one man can reach around the bars and mount up the various frame attachments.



4-6-0 TYPE EXPRESS LOCOMOTIVE, BAVARIAN STATE RAILWAYS.

When we look into details of construction further comparison with the American locomotive can only be very unfavourable to this latter. In place of the unwieldy masses of metal which American builders put into all the motion rods, we have here, as in most European locomotives, very finely-wrought and elegantly proportioned rods, which are able to resist every stress that may be put upon them without the gross dead-weight which has to be thrown around with the wheels of American engines.

The crank-axle is a superb piece of work, having an oblique arm, between the cranks, of a heavy rectangular section, finished bright all over and with a 2-in. hole bored right through the crank-cheeks and through the corresponding crank-pins.

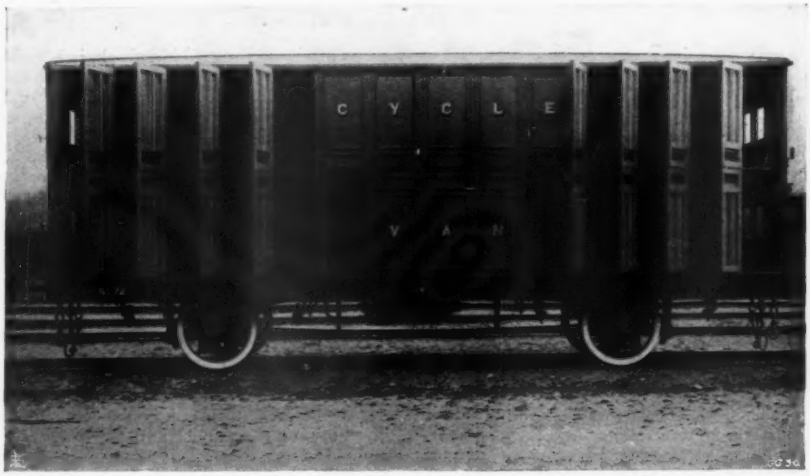
All motion of the four valves is derived from a single pair of Walschaerts' valve-gears, direct, as usual, for the low-pressure outside valves, and indirect, by rocking-levers and shaft, for the inside high-pressure cylinders. These rocking-levers are connected to the top of the advance-lever. All the valves have the same relative length of travel or cut-off. They cannot be varied *en route* by the driver, as where four sets of valve-gears are provided, but the travel of the low-pressure can be set for a later cut-off if found desirable for the nature of the work to be done by the engine. The use of four sets of valve-gears is now being abandoned, even where four sets were formerly used, the advantage derived from their use being found so slight.

A novel disposition is employed for lifting the link radius-bar, which, instead of terminating as usual at the link, is extended beyond, its extremity being pinned to a broad hanging link in connection with the arm of the weigh-bar shaft. The weigh-bar shaft and the rocking shaft are fitted in bearings upon special steel-casting brackets fixed above the cross-head guides. All the valves are of piston type, with external exhaust.

The boiler is connected with the frames at the smoke-box by the customary expansion slides under the fire-box foundation ring, and also by deep flexible plates at the level of the first and third barrel rings. The boiler-head or back of fire-box has a considerable inclination from the vertical. The fire-box sheathing is perforated in correspondence with the hole in each of the copper screw-stays. The smoke-box door is cast in iron in the form of a cone, which should be better able to resist buckling and so keep a tight fit. The regulator handle has an articulated joint for low reach on the driver's (right-hand) side. It has in addition a notched sector, with spring latch for fixing the regulator handle. The cab has the ample dimensions of the great railway cars of the Bavarian lines, and is fitted up with the extensive equipment usual on the Continent for the control and care of the machine *en route*, including the usual Haussh'lter tachograph. The tender is carried on two four-wheeled bogies, and has a capacity for 21 tons of water and 7 tons of coal.

A number of these large engines is now at work on various main lines, starting from Munich, hauling heavy express trains with especial satisfaction as to their steaming powers, and also with regard to their steadiness of movement at high speeds.

The principal dimensions of these engines are: Cylinders 13¾ ins. diameter for high-pressure (inside), and 22½ ins. diameter for low-pressure (outside), with a stroke of 25½ ins. for all four. Driving-wheels 6 ft. 1⅛ in. diameter. Bogie-wheels 3 ft. 1⅜ in. diameter. Tubes, 283, have a



CYCLE VAN, GREAT NORTH OF SCOTLAND RAILWAY.

heating surface of 2,097 sq. ft., and the fire-box of 150 sq. ft., or a total of 2,247 sq. ft. The grate area is 35 sq. ft., and the boiler pressure 205 lbs. for this six-coupled class of locomotives, although others of the same general construction and size carry over 235 lbs. pressure to the sq. in.

The tractive effort of the engines is 6 tons. They have a total height of 14 ft. 10 ins., and the boiler centre has a height of 9 ft. 6 ins. Their greatest width is 10 ft. 2 ins. Their length over all is 38 ft. 7 ins., and together with the tender they measure 63 ft.

The engines are of remarkably light weight for the great size of the boiler. Empty they only weigh 62·2 metric tons, or 70·8 tons when fully loaded—of which 47·8 tons is available for adhesion, giving a co-efficient of nearly 8.

The tenders weigh empty 26 tons, or loaded 54 tons, so that the maximum weight of the engine and tender reaches, when starting on a trip, 124·8 tons.

These locomotives were designed and constructed by the works of J. A. Maffei, of Munich.

A Novel Cycle Van

THE Great North of Scotland Railway have in operation an interesting type of cycle van, differing from those in use on other systems. By the courtesy of Mr. W. Pickersgill, Locomotive Superintendent of the Great North of Scotland Railway, we are enabled to give an illustration and some leading particulars of this vehicle.

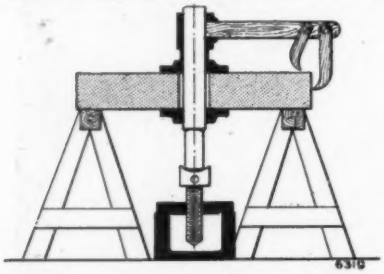
The body, it will be seen, is constructed in two stories, each of which is separated into 14 compartments or stalls, thus providing accommodation for 28 bicycles. A separate stall is provided for each machine, which is led into and held in position by guides screwed to the floor of each compartment. At a convenient height above each set of floor boards padding 12 ins. deep has been provided to allow for variation in the height of the handle-bars. This padding extends 1 in. on either side of an interior board, which is 1 in. thick, the padding consisting of wood shavings covered with canvas, an arrangement which ensures the cycles being carried with perfect safety. A door is provided for each side of the compartments; and fitted to the door-framing is a hinged slate panel, carried in a separate frame, by means of which an inspection can be made of the interior compartment without the necessity of opening the maindoor. These slate panels are conveniently placed, so that the destination of the bicycles can be written on them. Each door is secured by a Maxwell's lock, in addition to a private Budget lock. The under-frame is made of oak, and is pitched as low as possible to allow as much head-room as possible for the bicycles. The vehicle is fitted with a Westinghouse quick-acting brake.

The leading dimensions are as follows:—

Length of body, 28 ft. 6¾ ins.
Length over headstocks, 28 ft. 6 ins.
Length over buffers, 32 ft.
Width of body outside, 7 ft. 0½ in.
Height from rail to outside of roof, 12 ft. 8 ins.
Height from rail to centre of buffers, 3 ft. 4½ ins.
Total wheel base, 16 ft.
Diameter of wheels at tread, 3 ft. 1½ ins.
Centre to centre of axle journals, 6 ft. 8 ins.
Size of journals, 8 ins. by 4 ins.
Clear doorway upper storey, 3 ft. 10½ ins. by 1 ft. 9¾ ins.
Clear doorway lower storey, 3 ft. 11 ins. by 1 ft. 9¾ ins.

Fixing a New Grindstone.

A very effective method is to place the stone as shown in sketch, levelled up on two tressels. Insert the shaft with one flange butting against a fixed collar on the



same from the underside, and press up against the face of the stone by means of an ordinary lathe screw-jack resting upon a suitable support, leaving off the top flange and nut until the shaft is set correctly. A piece of timber, say 1½ ins. thick, is bored at one end to fit the shaft, and supported with a collar on the underside. Two pointers, as shown, are fixed with wood screws for adjusting purposes. This improvised trammel is then rotated, the pointers indicating the full parts both on face and circumference, thus showing the direction in which the shaft must be moved. The shaft, when square and central with the stone, and while in this position, is run with molten lead between the shaft and rough bore of the stone, and care should be taken to have a sufficient quantity to fill up completely before the metal sets. When set, remove the trammel from the shaft, and trim any surplus lead off level with the face of the stone. Now place the other flange on, and tighten up with the nut. Pieces of roofing felt make very good packing between the flanges and the faces of the stone. Lift the stone into position, and on trial it will be found to run surprisingly true.

GAUGER.

METALLURGICAL PROGRESS.

By PERCY LONGMUIR, Carnegie Research Scholar.

Steel.

Steels containing Titanium. Much has been written on titanium in cast-iron and steel, but comparatively few definite properties induced by the presence of this element have been given. We therefore turn with anticipation to a research of M. L. Guillet's on titanium steels, contained in a recent issue of the *Revue de Métallurgie.* In endeavouring to follow his usual plan of investigation, some difficulty was encountered in making the first series, owing to the high content of carbon contained in the ferro-titanium used. As a result, the highest content of titanium in the low carbon series is found at 3 per cent. Of the second series, containing 0·7 per cent. carbon, steels have been examined containing up to 10 per cent. titanium. In attempting to exceed this latter content, an insurmountable difficulty is met with in fusing the alloys—at any rate, as far as ordinary steel-works crucible furnaces are concerned. Tensile tests of the steels present no unusual features; the mild series containing from 0·415 per cent. to 2·57 per cent. titanium, all yielding very similar values. Similar tests of the second series, which contains about 0·7 per cent. carbon, and titanium varying from 0·325 per cent. to 8·710 per cent., also show little variation; if anything, the highest content of titanium yields the greatest breaking load and limit of elasticity, but the increase is not specially marked. The metallographic features of the alloys also show no dissimilarity from ordinary carbon steels. Titanium up to 7 per cent. does not modify the structure; it is apparently dissolved in the iron, a conclusion supported by the results of quenching and annealing experiments. The results of mechanical tests and micrographic examination show titanium to have no sensible influence on the properties of carbon steels, and that titanium steels present comparatively little industrial interest.

Steels containing Tin. These steels, according to the results of M. Guillet's * work, do not possess much industrial value, they present however some interesting features worthy of note. The contents of carbon and tin the alloys prepared are as follows:—

First Series.		Second Series.	
Carbon %.	Tin %.	Carbon %.	Tin %.
0·204	1·79	0·760	2·05
0·152	5·02	0·665	4·80
0·100	9·98	0·767	9·75

With the exception of the first member of the second series, none of the steels would forge, a feature attributed to two causes: (1) the high mineralogical hardness, and (2) the extreme fragility of the steels. As a result of this failure to forge no mechanical tests are given; emphasis is however laid on the fragility and hardness. The micrographic features of the alloys are not very dissimilar to those of ordinary iron carbon steels, and the first series up to 5 per cent. tin present normal ferrite and pearlite. Exceeding 5 per cent. tin the pearlite areas appear to be surrounded with white patches which sometimes take a needle form. The second series present similar features, and from the microscopical examination it is concluded that in tin steels containing less than 10 per cent. tin all the carbon is in the state of carbide of iron, whilst the tin is held in solution in the iron. Experiments on quenching and annealing have, as far as structure is concerned, yielded similar results to those obtained from carbon steels. Tin does not aid the precipitation of free carbon, for annealing at 1200° Cent. for 10 hrs. has in no case produced graphite. Cementation experiments have shown that the presence of tin considerably retards the process of cementation. Finally M. Guillet, from his many experiments on cementation with various special steels, reaches the following conclusion:—"Elements which dissolve in iron diminish the speed of cementation, whilst elements which form carbides increase it." From the tabulated results we gather that the presence of nickel, titanium, silicon, or aluminium diminish the speed of carbon penetration, whilst manganese, tungsten, chromium, and molybdenum increase it.

*Tensile and Impact Tests of Metals.** Mr. W. K. Hatt has investigated the relative behaviour of metals under impact and gradual loading in tension, the results being presented to the American Society for testing materials. The results are summarised in the appended table:—

* *Revue de Métallurgie.* Vol. i., No. 9.

* *Transport and Railroad Gazette.* Vol. xxxvii., No. 11.

TABLE SHOWING COMPARATIVE TESTS UNDER GRADUAL AND IMPACT LOADING IN TENSION.

Except where noted impact tests were made with one blow at atmospheric temperature on test bars of the same length as used in gradual tests. Elongation is that after Rupture. Rupture work is that up to Rupture.

No.	Material.	Diameter. Inches.	Gauge Length. Inches.	Ultimate strength. lbs. per sq. in.	No. Tested.	Elongation %.			Rupture work. ft.-lbs. per cub. in.			Kind of Test.
						Max.	Min.	Average.	Max.	Min.	Average.	
1	Steel wire	0·16	48	115,000	2	0·71	0·48	0·59	144	130	138	Gradual
		—	108	—	4	1 00	0·42	0 70	208	165	186	Impact
2	Steel wire annealed	0·16	48	83,000	1	—	—	9·30	—	—	566	Gradual
		—	108	—	5	11·0	8·7	9·8	803	648	772	Impact
		—	48	—	2	8·0	6·0	7·0	534	534	534	Impact
3	Steel wire	0·30	72	71,800	5	15·8	12·8	14·1	865	690	742	Gradual
		—	108		6	15·6	12·0	13·6	903	515	765	Impact
4	Steel wire	0·26	108	109,000	2	4·64	4·62	4·63	349	347	348	Gradual
		—	108	—	15	7·0	4·0	5·10	699	443	536	Impact
		—	69	—	5	7·0	5·0	5·80	673	596	626	Impact
5	Nickel steel ...	0·30	8	83,000	6	26·7	22·1	23·6	1505	1360	1414	Gradual
		—	8	—	8	29·4	20·7	24·0	2216	1203	1821	Impact
6	Soft steel	0·30	8	68,000	7	26·3	21·9	23·9	1532	1260	1376	Gradual
		—	8	—	13	31·6	23·1	27·0	1460	1208	1358	Impact
7	Boiler plate steel...	1·0	8	60, 00	19	29 0	23·2	25·7	1370	1047	1230	Gradual
		0·5	8	—	4	36·9	31·3	34·4	2035	1690	1855	Impact (2 blows)
8	Soft steel castings	0·5	2	62,000	5	29·5	26·5	28·2	1666	1342	1450	Gradual
		—	—	82,000	—	—	31·0	33·0	2467	2080	2315	Impact
9	Hard steel castings	—	—	—	—	—	—	—	—	—	—	—
		—	—	—	5	35·0	—	—	—	—	—	—
10	Locomotive tire steel	0·62	3	140,000	30	30·0	3·0	13·1	2000	212	976	Gradual
		—	—	60,000	30	37·0	3·0	14·3	5650	890	2918	Impact
11	Norway iron ...	0·305	72	63,000	1	—	—	18·7	—	—	649	Gradual
		—	108	—	3	19·4	16·7	18·1	727	550	656	Impact

Blast-Furnace Practice.

Gayley Method of Extracting Moisture from Air.—This process is designed to render the amount of moisture entering a furnace constant irrespective of atmospheric variations. To attain this Mr. Gayley removes the moisture by refrigeration, employing as a cooling agent anhydrous ammonia which on evaporation produces a low temperature. Air passes into a refrigerating chamber fitted with a series of pipes containing anhydrous ammonia, the moisture of the air is deposited as snow on the pipes, and the dried air is passed into a reservoir from which it is led to the blowing engine.

*Special Forms of Blast-Furnace Charging Apparatus.** In a paper read before the American Institute of Mining Engineers Mr. T. F. Witherbee examines at length various types of charging bells. One specially interesting point raised in this paper is found in a reference to the defects developed in working the exceptionally large American furnaces, viz. :—That these defects are not due to the size but the manner in which the materials including blast have been distributed. If the reported fuel consumption of these furnaces could be reduced to the best records of the smaller furnaces a saving of over 100,000 dols. per year would be effected. The suggestion is made that better results might be had by charging nearer to the centre, so as to have a more resistant column there to blow against, thereby enabling a reduction of the tuyere area enough to minimise blast wandering and its train of evils. At present, with large charging bells it is necessary to employ tuyeres from 50 to 60 per cent. too large, thus practically surrendering all control of the blast at the bustle pipe, from which it can enter the furnace through any tuyeres offering a relatively smaller resistance.

* *Iron Trade Review.* Vol. xxxvii., No. 38.

*Blast-Furnace Slag as a Structural Material.** Mr. J. A. Shinn deals with various aspects of slag as structural material. If blast-furnace slag were used for all purposes for which it is more economical or more suitable than material now in use, the order of quantities used would be somewhat as follows: 1. As sand, for concrete street paving, building block and rubble masonry. 2. In brick, for foundations, superstructure and refractory purposes. 3. As aggregate for concrete, roofing, etc. 4. In the manufacture of Portland cement. 5. In the manufacture of Pozzuolani cement. 6. In the manufacture of slag-wool for non-conducting purposes. The value of these products per unit of weight is about the reverse of this order.

* Engineers' Society of Western Pennsylvania and *Iron and Steel Magazine.* Vol. viii., No. 8.

General.

*Hedburg's Simplex Process for Separating Refractory Zinc Ores.** This process is designed to separate iron and sulphur from zinc ores, enhancing the value of the ore and at the same time effecting the recovery of two by-products. The average Wisconsin mill concentrates contain 10 per cent. iron, 10 per cent. sulphur, and 73 per cent. zinc blende. The plan in treating these concentrates is as follows: On arrival at the separating plant the ores are placed in a chamber, having a cast-iron floor, below which roaster gases are circulated for drying. The dried material is crushed and screened to a size of from $\frac{1}{32}$ to $\frac{1}{8}$th of an in., and carried by conveyors to the roasters. These consist of two cylinders, lined internally with fire-brick, and revolving slowly on friction wheels placed below. Roasting is continuous, and as the ore travels through, the iron is oxidised and the sulphur volatilised, the zinc remaining unaffected. The expelled sulphur is collected and passed on to a sulphuric acid plant. The ore on emerging from the roaster is conveyed into a gas chamber where the iron becomes magnetised, and is afterwards removed by means of electro-magnetic separators. This iron is subsequently passed on to a pigment plant for manufacturing paint. The value of the process is stated to lie in its continuity, the effective removal of iron and sulphur from the ore, and their conversion into saleable products.

Some Neglected Details in the Experimental Study of Alloys. Mr. E. S. Shepherd, in a late issue of the *Iron and Steel Magazine*, endeavours to point out several experimental details which have been neglected in recently published researches on alloys. Special emphasis is laid on pyrometric observations and the necessity for determining the secondary breaks in cooling curves—a necessity which in the author's opinion has not received full recognition. In much of the work devoted to determining freezing points proper precautions are not taken to prevent surfusion, hence many of the published results are probably low. It is also further stated:—"Not since the classic researches of Heycock and Neville has efficient stirring been maintained, if it has been attempted. This is synonymous with saying that there has not been a really accurate freezing point curve determined since the above-mentioned work." Mr. Shepherd may have some truth in his criticisms, nevertheless it is surprising that a writer so hypercritical confuses the elementary terms "brass" and "bronze," and an alloy of 50 per cent. copper, 50 per cent. tin is actually described as a "brass."

* R. T. Clegg, *Mining World.* Vol. xxi., No. 11.

*Alloys of Zinc and Magnesium.** Alloys of zinc and magnesium are hard and brittle, presenting a more or less brilliant white colour and are of comparatively low fusibility. The actual solidification points, as determined by Dr. Boudouard, are embodied in the following table:—

Magnesium %	Zinc %	Freezing Point. Degrees Centigrade.
—	100	420
5	95	355
10	90	545
15	85	570
20	80	570
25	75	527
30	70	495
40	60	340
50	50	366
60	40	430
70	30	495
80	20	558
90	10	600
100	—	635

These results when plotted into the form of a freezing point curve present a maximum at 570° and two minima at 355° Cent. and 340° Cent. The maximum point denotes the existence of a compound responding to the formula Zn^2Mg. Microscopical evidence also points to the existence of a further combination corresponding to the formula $ZnMg_4$.

* *Revue de Métallurgie.* Vol. i., No. 10.

ABSTRACTS.

A Scientific Investigation into the Possibilities of Gas Turbines.

By MR. R. M. NEILSON, A.M.I.Mech.E.

Proceedings Institution Mechanical Engineers, Oct. 21, 1904.

A PROPHECY expressed frequently in engineering circles at the present day is that turbines actuated by hot gases, other than steam, will eventually come to the front as prime movers. The idea of employing hot gases (other than steam) to drive a turbine is by no means new; but the success of the steam turbine has recently brought the question into prominence.

There is no doubt that many persons speak of the advantages of gas turbines without duly considering the difficulties to be encountered. There are probably many others who have valuable ideas on the subject, supported in some cases by experimental data, but who are apt to let their thoughts run in a groove, and to consider (rightly or wrongly) that the only possible solution of the gas-turbine problem lies in the particular direction in which they are working.

This paper is written with the object of expressing and comparing as concisely as possible the advantages and possibilities of gas turbines worked on different cycles, and the difficulties to be overcome to make these turbines a success.

Carnot's formula for the efficiency of an ideal heat-engine

$$E = \frac{T_1 - T_2}{T_1}$$

is well known, but its real meaning is sometimes forgotten; and it may not be out of place here to put in a reminder that, in Carnot's cycle, *all* the heat is put in at temperature T_1, and *all* the heat withdrawn at temperature T_2. An increase in the range of temperature does not necessarily cause a thermodynamic gain, and it is possible largely to increase the range of temperature (as for example by superheating steam before use in steam-engine) without thermodynamically increasing the efficiency by more than a small percentage.

If we have a gas-engine (reciprocating or turbine) working on Carnot's cycle between the limits of temperature 1,600 degs. Cent. (2,912 degs. Fahr.), and 17 degs. Cent., its greatest possible efficiency will be:—

$$\frac{(1600 + 273) - (17 + 273)}{1600 + 273} = 0{\cdot}85.$$

If the gas-engine is an explosion motor with compression to 60 lbs. per sq. in. above atmosphere, combustion at constant volume, and expansion to atmospheric pressure, the greatest possible efficiency between the same limits of temperature is only 0·50; and, if the engine work on the ordinary Otto cycle with the same compression and between the same limits of temperature, the greatest possible efficiency is only 0·37.

We must therefore strive not so much to get the maximum and minimum temperatures respectively as high and as low as possible, but to get the mean temperature at which heat is given to the gas and the mean temperature at which heat is withdrawn from it respectively as high and as low as possible. Of these two temperatures the lower one is usually by far the more important. An ideal gas-engine working on Carnot's cycle between the limits of temperature 2,000 degs Cent. abs., and 300 degs. Cent. abs., will lose as much by an increase of 100 degs. Cent. to the lower temperature as it will by a decrease of 500 degs. Cent. from the higher temperature.

Coming now to discuss more particularly gas-turbines, there are four cycles on which it seems to the author that these could be worked with the possibility of good results. Two of these are what Mr. Dugald Clerk designates Type 2 and Type 3. The author calls them respectively Cycle I. and Cycle II.

A pressure volume diagram of an engine working on Cycle I. is shown in Fig. 1, and an entropy-temperature diagram in Fig. 2.

The working fluid is compressed adiabatically from *A* to *B*. Heat is then supplied by combustion at constant pressure from *B* to *C*. The gas then expands adiabatically from *C* to *D*. The fluid is then cooled at constant pressure from *D* to *A*. Reciprocating gas-engines have been worked on this cycle by Brayton and others, but have never come into common use. (The Diesel engine may be considered to belong to this class, although no decided constant pressure line is discernible on indicator diagrams taken from the engine.) One great difficulty that has been experienced in working reciprocating engines on this cycle is that of getting complete combustion during the period *B C* without the charge occasionally firing back. If the air and fuel are brought into contact only on entering the cylinder, it is difficult to get good combustion during the period *B C*. If, on the other hand, the air and fuel are previously mixed together, it is difficult to prevent occasional firing back. Of course the chamber in which the air and fuel are mixed may be made strong enough to stand explosions; but any back firing upsets the

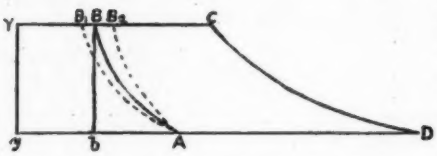


FIG. 1.—PRESSURE-VOLUME DIAGRAM.

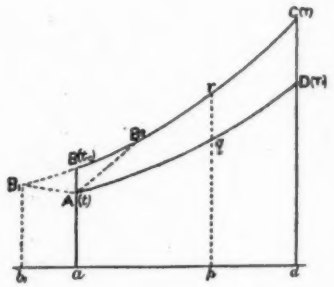


FIG. 2.—ENTROPY-TEMPERATURE DIAGRAM.

regular working of the engine and is otherwise objectionable.

It has been proposed for gas-turbines to cause air and fuel to unite in a nozzle which thereafter diverges, with the idea that the air and fuel will combine on meeting each other and the hot products of combustion then acquire a high velocity in the divergent nozzle with which velocity they will enter the turbine buckets. The results of a trial of such a scheme would be interesting. The author doubts if the combustion would be quick enough to give a good efficiency. If, however, a combustion chamber of ample size were provided in which the burning gases could rest a short interval before passing to the turbine, better results could, in the author's opinion, be expected. The air and fuel would be separately pumped into the chamber from which the products of combustion would flow continuously and uniformly by one or more passages into the turbine.

At any rate the difficulties should not be as great with turbines working on this cycle as with reciprocating engines, as the latter have to receive the hot gases intermittently while the turbine receives a continuous flow. This is an important point as regards controlling the flame. With an engine of the Brayton type the fuel has to be ignited in the cylinder for every working stroke, and the supply of gas to the flame has to be cut off for every working stroke. With a turbine the fuel and air could be supplied at a constant velocity to the flame and a steady flame maintained without interruptions. This is important because, if a mixture of air and fuel be always supplied to the flame with a velocity greater than the velocity of propagation of the flame, there can of course be no firing back, and this result can be obtained without the use of a wire-gauze screen. The maintaining of this velocity of supply to the flame above the required minimum when starting and stopping the motor, and when running at low powers, is of course a problem to be considered. The strength of the mixture of air and fuel should be kept constant. The power of the turbine can be varied by other means, which will be referred to later. It must be noted that if the air and fuel are compressed adiabatically to a sufficient extent, which depends on the nature of the fuel, combustion will occur immediately the two are brought into contact with each other. It is therefore necessary in such cases to keep the air and fuel apart until the instant when combustion is desired. It must also be noted that with a turbine there will be no hot waste-gases mixed with the fresh air and gas to be compressed.

This cycle allows of a fairly high ideal efficiency being obtained with a moderate maximum temperature. Now a moderate maximum temperature is of the utmost importance in the case of a turbine of the Parsons type. A Parsons turbine with steel blades could probably be designed without any great difficulty to stand a temperature of about 700 degs. Cent. without any water jacketing or cooling devices of any sort (except for the bearings). With temperatures above this, the blades would need to be cooled. This would necessitate a radical alteration in design. It is only desired here to point out that great difficulties with a certain class of turbine are avoided by keeping the maximum temperature moderate. The cycle we are considering may therefore have great advantages for turbines.

It had better be stated here that the author has made several assumptions with regard to the working fluid or fluids. These assumptions are as follows:—

(1.) That the specific heats of gases dealt with are constant at all temperatures and pressures, and are as follows:—

Specific heat at constant pressure or Kp = 0·238.

Specific heat at constant volume or Kv = 0·17.

(2.) That weight per cub. ft. of gases dealt with = 0·0777 lbs. at a pressure of 15 lbs. per sq. in. abs. and a temperature of 17 degs. Cent.

(3.) That $\frac{PV}{T}$ = a constant for all pressures and temperatures.

(4.) That PV = a constant for isothermal expansion and compression at all temperatures and pressures.

(5.) That combustion produces no change of volume except that due to change of temperature.

Some of these assumptions will probably be appreciably inaccurate in certain cases; but it seemed advisable to sacrifice something for simplicity and uniformity.

Referring to Fig. 2, the heat absorbed by the fluid is represented in this figure by the area

aBCd, and the heat abstracted or discarded by the area *aADd*. The heat converted into work is represented by the area *ABCD*, and consequently, if *E* represents the ideal efficiency of an engine working on this cycle,

$$E = \frac{\text{area } ABCD}{\text{area } aBCd}$$

Now it can be proved that $\frac{AB}{aB} = \frac{DC}{dC} = \frac{qr}{pr}$

where *pqr* is any ordinate cutting the lines *ad*, *AD*, and *BC*, which are all constant pressure lines.

$$\text{Therefore } E = \frac{AB}{aB} = \frac{DC}{dC} \qquad (1)$$

Let t represent the temperature before compression.

Let t_c represent the temperature at the end of compression.

Let T represent the temperature at the end of combustion.

Let T_1 represent the temperature at the end of adiabatic expansion.

Then from equation (1), and referring to Fig. 2,

$$E = \frac{t_c - t}{t_c} = \frac{T - T_1}{T}$$

It is important to consider the amount of negative work done and the ratio of this to the total or gross work. The negative work is the work of compressing the gas and delivering it in its compressed state. It is true that with some engines there is no work of delivery. In a reciprocating gas engine in which the gas is compressed in the motor cylinder, the only negative work (ideally) is that of compressing the charge; and even when a separate cylinder is used for the compression, the work of delivering might be avoided. With a turbine, however, the fluid cannot be compressed in the motor; and whatever arrangement is adopted, the compressed fluid will have to be delivered after compression. The author has therefore considered it better in all cases to include in the negative work the amount required to deliver the compressed gas. The motor proper, of course, gets the benefit of this work.

In Fig. 1 the work to compress the gas is represented by the area *AbB*, and the work to deliver it in a compressed state by the area *yVBb*. The total negative work is therefore represented by the area *yVBA*. The gross work of the motor is represented by the area *yVCD*, of which the part *yVBb* represents the work done before expansion, and the part *bBCD* the work done during expansion. By deducting the negative work from the gross work the net work is obtained; this is represented by the area *ABCD*. This net work is the same as that represented on the entropy temperature diagram (Fig. 2) by the area *ABCD* on that diagram.

Cycle I, Case 1.—If the gas is required to be used in a Parsons turbine without cooling arrangements the maximum temperature must not exceed 700 degs. Cent. A case with this maximum temperature will now be considered.

Suppose that in all cases t = 17 degs. Cent. (290 degs. abs. Cent.) and the corresponding pressure = 15 lbs. abs. Let us first try compressing to 42 lbs. abs.; t_c will then be 389 degs. abs. Cent.

Let heat now be supplied and the gas expand at constant pressure till the temperature is 973 degs. abs. Cent. Let the gas now expand adiabatically till the pressure falls to 15 lbs. abs. The fluid is now exhausted into atmosphere, and as the new charge is taken at the same pressure and at temperature t, we can assume that the discharged gas is cooled at constant pressure and used over again.

E is therefore equal to 0·25, and the ratio of negative to gross work 0·4.

In dealing with large volumes and small pressures there is an immense difference between turbines and reciprocating engines. Reciprocating engines require large cylinders. These large cylinders, besides being objectionable on account of bulk and cost, necessitate great frictional losses. The low pressure dealt with is of little import as regards friction, which will be nearly the same whether the pressure is 13 lbs. below atmosphere or 13 lbs. above atmosphere. With a turbine, however, the large volume of the fluid does not necessitate such a bulky machine. Moreover, in a turbine the friction depends on the pressure. With high pressures the friction is great, with low pressures very small. (In marine propulsion by steam-turbines it is not considered worth while uncoupling the reversing turbines when the vessel is going ahead.) These turbines are allowed to rotate (above their normal speed) in the low pressure which exists at the exhaust ends of the main low-pressure turbines.

Cycle I, Case 2.—700 degs. Cent. must not, however, be considered as the limiting temperature for gas-turbines. We can employ a much higher temperature if we use water cooling or other cooling arrangements.

It has been proposed by Mr. Parsons and others to circulate water or other cooling fluid through the actual blades of a turbine, these being formed hollow. It has also been proposed to keep the blades of a single-wheel turbine cool by causing the actuating fluid to act only at one point of the circumference of the wheel, while a cooling fluid is projected on to the blades at another point.

By the employment of cooling devices we might possibly get a turbine to stand a temperature of 1,500 degs. Cent., or even 2,000 degs. Cent. 2,000 degs. Cent. is a very high temperature, and there would be great difficulty in devising and constructing cooling arrangements that would keep the blades in good working order when acted on by gas at a temperature approaching this. Let us assume, however, that 2,000 degs. Cent. is allowable for our maximum temperature; then, if we keep the same compression as in Case 1, E can be shown to equal ·25.

The increase in the maximum temperature has therefore added nothing to the efficiency, and this will always be the case if the initial temperature and pressure are unchanged and we compress to the same amount.

The negative work is the same as in the last

case, and the ratio of gross to negative work = 0·171. We have therefore very considerably diminished the ratio of negative work to gross work.

Cycle I, Case 3.—In Case 1 it was necessary to have a low compression because a high compression with a maximum temperature of only 700 degs. Cent. would have given an impracticably high value to the ratio of negative work to gross work. In fact this ratio was high even with the low compression adopted.

With the maximum temperature raised to 2,000 degs. Cent., however, a much higher compression can be adopted. Suppose a compression to 300 lbs. per sq. in. abs. is adopted. This will make t_c 682·5 degs. abs. Cent., whence it is shown that E = ·58, which is much better than (more than double) that in Cases 1 and 2. There is, however, the inconvenience of a high compression, and compared with Case 1 more heat is likely to be lost through radiation owing to the higher average temperature. This question of radiation will be more or less important according to the type of turbine.

In this case the

$$\frac{\text{neg. work}}{\text{gross work}} = 0{\cdot}3.$$

Cycle I, Case 4.—It will be interesting to find what efficiency can be obtained with a maximum temperature of 2,000 degs. Cent. by increasing the compression till the ratio of negative work to gross work is 0·4—the same as in Case 1. This ratio will be attained when t = 909 abs. Cent. which corresponds to a pressure of 818 lbs. abs. Then

$$E = \frac{909 - 290}{909} = 0{\cdot}68.$$

In every case it has been assumed that the compression is adiabatic; it is usually important that it should be at least nearly so.

It is in general disadvantageous to heat the air or fuel before compression, no matter what be the source of heat.

If gas is allowed to enter a water-cooled turbine at a high temperature, such as 2,000 degs. Cent., there will necessarily be a great amount of heat carried away by the water. In a reciprocating engine the metal surface with which the gas comes into contact is very small compared with that in a multiple expansion turbine; and in a reciprocating engine the bulk of the gas may expand and fall from its maximum temperature to the temperature at exhaust without ever coming near a metal surface. In a multiple expansion turbine, on the other hand, every particle of gas must practically slide along a metal surface immediately it comes to the first ring of blades. With turbines employing gas which enters the turbine casing at such a temperature, the heat lost through the walls and carried away by the water must necessarily be very great indeed. It is true that the metal surface in contact with the gas can be allowed to be at a much higher temperature than the inside of the cylinder walls of a reciprocating engine; but, in spite of this, the heat lost through the walls and carried away by the cooling water will probably be much greater with a turbine actuated by gas entering the turbine casing at about 2,000 degs. Cent. than in a reciprocating engine in which the maximum temperature is 2,000 degs. Cent. This loss of heat will cause the actual work done by the engine to be very much below the ideal. This is not only important in itself, but it prevents us usefully employing a high ratio of negative work to gross work.

Cycle I, Case 3a.—Instead of employing cooling arrangements for the metal, some or all of the available heat energy of the gas can be converted into kinetic energy before causing it to act on the turbine, so that the latter is not exposed to an unduly high temperature. This can be done by allowing the gas when at the maximum temperature to expand in a divergent nozzle till its temperature falls to a degree that the turbine can stand. More than one nozzle can be employed, but, to reduce the radiation losses, the nozzles should be large and few in number.

Suppose that the gas is compressed adiabatically to 300 lbs. abs. and then is heated at constant pressure to a temperature of 2,273 degs. abs. Cent., as in Case 3. If now the gas be allowed to expand in a suitable nozzle abiabatic expansion can be obtained; and if this be continued till the pressure falls to 15 lbs. abs. the temperature will be 966 abs. Cent. (693 degs. Cent.). This is just below the temperature which was fixed on as a maximum for a turbine without artificial cooling. E will therefore be the same as in Case 3; namely, 0·58. The ratio of negative work to gross work will also be the same as in Case 3, namely, 0·3. The velocity acquired works out at 5 290 ft. per sec.

To get the best results from a fluid velocity such as 5,290 ft. per sec., would require with a single turbine wheel a vane speed which cannot be obtained at present for want of a sufficiently strong and light material—the stresses produced by centrifugal force are too great. This difficulty is experienced with De Laval turbines. The obvious way out of the difficulty is to employ several wheels in series, the gas passing through the several wheels with diminishing velocity, but with nearly constant pressure. This has been done in steam turbines.

With the same object of reducing the vane speed, a device has been proposed whereby the nozzles are mounted on a wheel which rotates in the opposite direction to the wheel carrying the vanes. If the two wheels rotate at the same speed (in opposite directions) this speed will be half of that of the single wheel if the nozzles were stationary. The centrifugal force is therefore only one-fourth of what it would otherwise be.

The frictional losses in the nozzles of a gas turbine will probably be less than those in a steam turbine for the same velocity of exit from the nozzle.

Cycle I, Case 4a.—Let us now try working as in Case 4, but employing a divergent nozzle, as in Case 3*a*, to reduce the maximum temperature to 700 degs. Cent., so that the gas can be used in a turbine without cooling arrangements.

T_1 in this case will be 725 degs. abs. Cent. (452 degs. Cent.). It is not necessary therefore to perform all the adiabatic expansion in a divergent nozzle, but a portion of it can be performed in the turbine. If the fluid is expanded in the nozzle only till its temperature falls to 700 degs. Cent., the pressure will then be 42 lbs. abs.; so that 27 lbs. can be dropped in the turbine.

The velocity works out at 5,280 ft. per sec. *E* will be the same as in Case 4, and so will the ratio of negative work to gross work.

The author believes that an engine working on this cycle, according to Case 3*a* or Case 4*a* or between these, has good prospects. The ideal efficiency is high, from 0·58 to 0·68. How near one could approach this efficiency in practice would depend of course both on the losses in the motor proper and on the losses in the pump.

The losses in the motor proper may be taken to include the losses in the combustion chamber, if such is employed, and in the nozzles. The motor losses will then consist of:—(1.) Loss of heat by radiation and conduction. (2.) Fluid friction. (3.) Friction in turbine bearings. (4.) Loss due to incomplete expansion.

The first loss will be large, but should be less than in reciprocating engines, owing to the higher velocities employed and to the higher temperatures allowable in the metal.

The second loss will be considerable, but much less than in turbines using saturated steam. It has been found by experiment that hot dry air causes much less friction than wet steam.

The third loss will be trifling, and the fourth loss should be moderate. The discharge of heat with the exhaust gases is here only considered as a loss in so far as it exceeds that of an ideal engine.

It is difficult to estimate the pump losses. Rotary compressors on the turbine principle seem to have been employed only up to about 80 lbs. pressure. Whether or not they are suitable for high pressures is a point which we want very badly to know about. One would be inclined to believe that the fluid frictional losses with such machines would be very great if attempts were made to obtain high pressures. It by no means follows however that a fairly efficient rotary air-compressor cannot be devised.

A reciprocating compressor always has the disadvantage that the air when drawn in becomes heated by contact with the hot metal surfaces before compression commences. This evil is reduced by compounding. It is an evil that occurs to a serious extent with reciprocating gas-engines working on the Otto cycle.

With a reciprocating compressor it will be difficult to avoid the necessity of jacketing the cylinder if high compressions are employed. This will bring the compression curve below the adiabatic and reduce the efficiency.

In any case, whatever be the nature of the pump there is bound to be a certain amount of heat passed through the walls of the pump cylinders or casing. If this loss is made up by friction or impact within the pump, the compression may be along an adiabatic curve, but the loss will still have to be paid for.

The ratio of negative work to gross work is somewhat high, 0·3 to 0·4. In the case of a turbine one need not fear the increase in the bulk of the engine due to this high ratio; for the bulk of the turbine will probably be very small for the power. Frictional and other losses become however of much greater importance when the ratio is high. To show this forcibly, consider an extreme case. Suppose that the ratio of negative work to gross work in an ideal engine is 0·5, or in simpler language suppose that the pump requires half the gross power of the machine, there being no friction. If now the machine is not ideal, and if the mechanical efficiency of the pump is only $\frac{3}{5}$ and that of the motor proper only $\frac{3}{4}$, no useful work whatever will be got out of the machine—all the work will be absorbed by friction. For, if the power of the motor proper, including that spent on friction, is 100, the pump will require 50, and as its efficiency is $\frac{3}{5}$, it will take 75. This is exactly what the motor will give out after deducting friction. There will therefore be no power got out of the machine.

When there is a high ratio of negative work to gross work, success will therefore be dependent largely on the efficiency of the pump. Unless the pump is at least fairly efficient, success cannot be expected. In the Diesel engine the bulk of the air is compressed to about 500 lbs. per sq. in., and the air which carries the oil into the cylinder is compressed from 100 lbs. to 200 lbs. higher. It would be interesting to know with what efficiency the air is compressed in the Diesel engine.

Otto cycle reciprocating engines having ideal efficiencies of 0·4 to 0·45 have given practical efficiencies of half that amount. By practical efficiency is meant ratio of b.h.p. to thermal units in gas consumed, calculated on the higher calorific value. When the ideal efficiency is increased above 0·45, the ratio of practical efficiency to ideal efficiency usually falls below 0·5—the greater the ideal efficiency, the greater are the losses. With a turbine the losses ought also to increase when the ideal efficiency is increased, but whether to the same extent as with an Otto engine it is difficult to say. When considering high compressions it is well to note that the Diesel engine with a high compression and an incomplete expansion has given some of the highest practical efficiencies yet attained. The compression should not cause the same trouble in starting a turbine as in starting a reciprocating engine, as with a turbine we should be able to arrange that at every instant the gross work is greater than the negative work. With a reciprocating engine having a single cylinder working on the Otto cycle we have of course periods when the negative work exceeds the gross work.

Cycle II, Case 1.—With regard to explosion turbine engines, suppose that the fluid is compressed adiabatically to—say—101 lbs. per sq. in. abs., that ts to a temperature of 500 degs. abs. Cent. Let it now be heated at constant volume by explosion, and let there be a mixture of such a strength that the temperature will rise to 2,000 degs. Cent. (2,273 degs. abs. Cent.). The pres-

sure will then be 459 lbs. abs. If the gas is now allowed to expand adiabatically till its pressure is atmospheric (when its temperature will be 855 degs. abs. Cent.), and then cooled at that pressure till it resumes its original state,

E will equal 0·55,

and the ratio of negative work to gross work = 0·23.

Cycle II, Case 1, very nearly resembles common practice to-day with reciprocating explosion engines. The expansion is, however, continued to atmospheric pressure. This, as a rule, is not desirable in a reciprocating engine on account of the extra length required to be given to the engine cylinder. This not only increases the loss by friction but increases the loss of heat by the expanding gas, and, if the same length of stroke is employed for drawing in the fresh charge, increases the heating of the charge before compression. The case, however, is very different with turbines; and there seems no good reason why with these the adiabatic expansion should not be carried practically to atmospheric pressure.

In practice the maximum pressure and the average maximum temperature throughout the gas would be less than the values here indicated owing to radiation losses.

Cycle II, Case 1a.—The gas could not be allowed into an uncooled turbine at the maximum temperature in Cycle II, Case 1; but, if the expansion were performed wholly or nearly wholly in a divergent nozzle, the temperature of exit from the nozzle would be sufficiently low to allow of the gas entering an uncooled turbine.

For example, if the gas at the maximum temperature of 2,273 degs. abs. Cent., and the maximum pressure of 459 lbs. abs. were expanded in a perfect divergent nozzle till the temperature fell to 700 degs. Cent. (973 degs. abs. Cent.) which was fixed on as the maximum allowable temperature in an uncooled turbine, the mean pressure on leaving the nozzle would be 23·5 lbs. abs., and the mean velocity 4,120 ft. per sec.

On comparing Cases 1 and 1*a* of Cycle II by reference to the Table with Cases 2, 3, 3*a*, 4 and 4*a* of Cycle I, which have the same maximum temperature, it is found that the efficiency is very much greater than Cycle I, Case 2, is nearly as great as Cycle I, Cases 3 and 3*a*, and is considerably below Cycle I, Cases 4 and 4*a*. The ratio of negative work to gross work is, however, greater than in Cycle I, Case 2, and less than in Cases 3, 3*a*, 4 and 4*a* of Cycle I.

There are two objections to the use for turbines of a Cycle such as Cycle II, and these objections must be set against the advantage which turbines would possess over reciprocating explosion motors, in being able to make better use of the tail end of the pressure volume diagram.

One of the objections is that explosions at constant volume have to take place intermittently, while a turbine desires a continuous supply of fluid. If the supply is not continuous the power of the turbine is less than it would otherwise be for a given size of machine; and the initial cost, the bulk and—most important—the loss by friction are greater in proportion to the power developed than they would otherwise be.

The other objection is that the fluid must leave the explosion chamber at varying pressure. This necessitates, unless special means are provided to prevent it, the fluid entering the turbine casing either at varying pressure or at varying velocity. This of course is objectionable, as the speed of rotation of the turbine cannot during the period of a cycle be made to vary correspondingly.

The second objection might be met by employing in a parallel flow turbine of the De Laval type long radial blades, and causing the nozzles to be altered in position according to the pressure, so as to direct the gas on to the outer ends of the blades at high pressures, and on to the inner ends of the blade at low pressures. The difficulty could also be met by an arrangement of reciprocating engine combined with a turbine, the gas being first expanded in the reciprocating-engine to a certain pressure, and then passed on to the turbine to complete its expansion. If several reciprocating cylinders were employed, the first objection also would be got over. It is true, that with such a combination some of the most important advantages of the turbine would be lost. The idea is, however, in the author's opinion, worthy of consideration. Reciprocating steam-engines have been successfully combined with steam-turbines in this manner.*

Cycle II, Case 2.—An explosion-engine in which a very high compression pressure is employed will now be considered. If compression be carried to 818 lbs. abs., as in Cycle I, Case 4, one obtains with a maximum temperature of 2,000 degs. Cent., a maximum pressure of 2,045 lbs. abs., and a very high ratio of negative work to gross work. If a much lower compression—namely 417 lbs. abs.—is adopted, this will give a temperature of compression of 750 degs. abs. Cent. Working on the same cycle as in the last case and arranging the explosive mixture to give a maximum temperature of 2,000 degs. Cent. (2,273 degs. abs. Cent.), a maximum pressure of 1,265 lbs. abs. is obtained, and E will equal 0·68, and the ratio of negative to gross work = 0·38.

E is the same as in Cycle I, Case 4, and the ratio of negative work to gross work is also the same. The compression is lower than in Cycle I, Case 4, but the maximum pressure is very much higher.

The excessively high maximum pressure is an objection to this case.

Cycle II, Case 2a.—If the expansion took place in an ideal divergent nozzle as before till the temperature fell to 700 degs. Cent. (973 degs. abs. Cent.), the gas would still have a pressure of 70 lbs. abs., while the mean velocity of exit from the nozzle would be 4,300 ft. per sec. If the gas were expanded in the nozzle down to 25 lbs. abs., the temperature would then be 741 abs. Cent., and the mean velocity of the gas leaving the nozzle would be 4,830 ft. per sec.

Cycle III, Case 1.—It has been proposed, when a water-jacket is employed, to utilise the heat

* *Cf.* ENGINEERING REVIEW. Vol. 10, pp. 214 to 224.

passed into the jacket water by causing this heat to generate steam from the water. This steam could then receive further heat from the products of combustion, which would therefore be reduced in temperature, while the steam would be superheated. The steam and products of combustion could then expand adiabatically, doing work in the same or in separate turbines. The carrying out of this idea would affect the efficiency in the several cases considered of Cycle I. Cooling arrangements are not required in Cycle I, Case 1, so this case need not be further considered. In Cycle I, Case 2, let it be supposed that the combustion-chamber is jacketed and that the jacket-water is heated and converted into steam by heat taken from the products of combustion, which have their temperature thus lowered from 2,000 degs. Cent. to 700 degs. Cent., that is to the temperature at which they can safely be allowed into an uncooled turbine, the steam being superheated up to 700 degs. Cent.

By thus transferring heat to the water and steam from the gas, E is therefore reduced. There must, however, in any case, as already mentioned, be lost in practice a large amount of heat from the products of combustion when these products of combustion enter the turbine casing at a temperature such as 2,000 degs. Cent., and, by adopting this combined steam and gas scheme, a much higher practical efficiency may possibly be obtained than would otherwise be possible. As the net work ideally is less than in Cycle I, Case 2, and as the negative work is not less (and may be greater by the amount of work required to pump the water into the jacket if under pressure), the ratio of negative work to gross work is increased. In Case 2 of Cycle I the ratio of negative work to gross work is low, and it will be therefore allowable to increase this ratio.

Cycle III, Case 2.—Case 3 of Cycle I could be modified in the same way by reducing the temperature of the products of combustion from 2,000 degs Cent. to 700 degs. Cent., and by employing the heat so given up in heating water and generating and superheating steam. The steam could be generated at 300 lbs. pressure abs. (the same pressure as the products of combustion) and superheated to 700 degs. Cent. at this pressure. The steam and gas could then be expanded adiabatically in the same or in separate turbines. As in the previous case, E would be reduced, and the ratio of negative work to gross work increased. As in the previous case also, the practical efficiency might be largely increased.

The fall in the value of E is due to the relatively low efficiency of the steam portion, which has an ideal efficiency of only 0·28. (This is really not low for a steam engine.)

Cycle II could be modified in the same way as Cycle I was modified by combining steam with the gas. A case of this nature has not been worked out; but Case 1 of Cycle II could probably be modified in this way. Case 2 of Cycle II could not be so treated on account of the high ratio of negative work to gross work that would occur.

One might try to improve on all these cycles by extending the adiabatic expansion line of the gas below atmosphere, instead of stopping it at atmospheric pressure. It would, of course, be necessary to compress the fluid back again to atmospheric pressure; but if this compression is isothermal, or between the isothermal and adiabatic, there will be an increase in efficiency. Carnot's cycle is, in fact, being approached in the lower part of the diagram.

A compression sufficiently near to the isothermal and sufficiently remote from the adiabatic to appreciably raise the efficiency, should be obtainable.

In the free piston explosion engines, at one time in fairly common use, of which the best known is the Otto and Langen, the expansion was carried to a pressure considerably below the atmosphere. The compression to atmospheric pressure which followed this must have been between the isothermal and the adiabatic.

If this continuation of the adiabatic expansion below atmospheric pressure is not found to be advisable to the extent that has just been described, it may be found advisable to a less extent. If it is found advisable in any case, it is more likely to be so in a case in which the high pressure of the gases after combustion is reduced to a low pressure in divergent nozzles, before the gas is allowed into the turbine casing, than in a case in which the whole fall of pressure takes place in the turbine casing. In the former case very high vane speeds are necessary, and the friction between the rotating parts and the fluid in the casing is an extremely important matter. The reduction of the pressure within the turbine casing from atmospheric pressure (or about that) to $\frac{1}{4}$ or $\frac{1}{8}$ of that amount may therefore very much reduce the frictional losses. It is true that the rotary pump, if such is employed for completing the cycle, has to deliver at atmospheric pressure, but the rotating parts of the pump can revolve at a much lower speed and the friction therefore be of much less consequence.

With such high-speed turbines there is another question to be considered. It has been stated in discussing Cases 3*a* and 4*a* of Cycle I and 1*a* and 2*a* of Cycle II that the velocity of the gases escaping from the divergent nozzles would be over 4,000 ft. per sec., if the heat energy converted into kinetic energy was as mentioned. The author is not however aware of any results of experiments having been published in which velocities of these amounts were obtained, when the pressure of the medium into which the divergent nozzle discharged was atmospheric. It is supposed by some that there is a maximum limit to the velocity of a gas leaving a divergent nozzle and escaping into a given medium which is at a given pressure, etc., and that this limiting velocity is dependent on the pressure in the medium into which the nozzle discharges, and is less when the pressure in this medium is greater and *vice versâ*. That is to say, it is supposed by some that, after a certain velocity of discharge has been attained, no increase in the initial temperature or pressure will increase this velocity; but a reduction of the pressure in the medium may increase this velocity. The author does not express any opinion himself

on this point, but if it should be found that the reduction of the pressure inside a turbine casing below atmospheric pressure enables us to convert the heat energy of our gas into kinetic energy more effectively, this will be a further argument in favour of so reducing the pressure. Whether or not there is an advantage to be gained remains to be proved, but there is at any rate a possibility of gain by thus extending the expansion, and a possibility which, in the author's opinion, should not be ignored. In dealing with large volumes and small pressures there is an immense difference between turbines aud reciprocating engines.

Cycle IV.—The fourth cycle is one in which a high ideal efficiency can be obtained with a low compression, and without having an abnormally high ratio of negative work to gross work.

Take a point in the cycle at which the temperature of the fluid is 1,592 degs. Cent. (1,865 degs. abs. Cent.). and the pressure is 30 lbs. abs.

Let the fluid be heated by combustion at constant pressure till the temperature reaches 2,000 degs. Cent. (2,273 degs. abs. Cent.). Now let the gas expand adiabatically till the pressure is atmospheric. The temperature will then be 1,592 degs. Cent. (1,865 degs. abs. Cent.). Now let the gas pass through a regenerating chamber and be cooled at a constant pressure till the temperature is 80 degs. Cent. (353 degs. abs. Cent.). The gas then escapes into atmosphere, and thereafter cools at constant pressure to 17 degs. Cent. (290 degs. abs. Cent.). At this point a new charge is taken and compressed adiabatically to where the pressure is 30 lbs. abs. and the temperature 80 degs. Cent. (353 degs. abs. Cent.). The fluid is now passed through the regenerating chamber, and is heated at constant pressure, taking back the heat given up by the last charge. This will raise its temperature to 1,592 degs. Cent. (1,865 degs. abs. Cent.) and place the fluid in the condition it was at the start.

The ratio of negative work to gross work is 0·16 and $E = 0{\cdot}84$.

The ideal efficiency is high; but the highest actual efficiency which could practically be obtained would be very much below this. Besides the losses in the motor proper and in the pump, there would be a very great loss in the regenerator. It would not be practicable to reduce the temperature of the exhausting gases in the regenerator to 80 degs. Cent., or to raise the temperature of the fresh gases in the regenerator to 1,592 degs. Cent.

If the losses in the regenerator and in the passages leading to it and from it amounted to 50 per cent. of the heat which is ideally given to or taken from the regenerator, these losses would have to be made up by extra heat given to the fluid by combustion, and the efficiency would fall to 0·3. This does not take into account the losses in the motor proper and in the pump. The heat losses in the motor would probably be very great. This cycle may, however, when used with turbines give results sufficiently good to justify its use. It certainly seems to promise better results with turbines than with reciprocating engines on account of the lower frictional losses that might be expected with turbines. With reciprocating engines the large volumes and the low pressure of the fluid would cause extremely high percentage losses in friction.

The cycle has the disadvantage that gas at a very high temperature has to be conveyed from the regenerator to the turbine. This practically forces us to have the turbine quite close to the regenerator. It would seem to be necessary to build the regenerator of brickwork, and to build the turbine into this brickwork. This will very much limit the usefulness of the cycle, as it will be quite infeasible in many cases either to have a regenerator of the nature required at the place where power is wanted, or to transmit the power from a place suitable for holding the regenerator. Nevertheless, there will be cases in which it will be quite practicable to build a regenerator beside the turbine and this cycle would therefore seem to be worthy of consideration. A rotary pump driven from the turbine spindle could easily be used for compressing the gases, thus simplifying the mechanical moving parts.

The several cases can be compared in the table.

TABLE

Comparing the several Cycles and Cases.

Cycle.	Case.	Compression.		Max. Temp abs. Cent.	Max. Press. lbs. per sq. in. abs.	Ideal Efficiency. (E)	Ratio of Neg. Work to Gross Work.
		Temp. abs. Cent.	Press. lbs. per sq. in. abs.				
I.	1	389	42	973	42	0·25	0·40
I.	2	389	42	2273	42	0·25	0·17
I.	3 & 3A	682·5	300	2273	300	0·58	0·30
I.	4 & 4A	909	818	2273	818	0·68	0 40
II.	1 & 1A	500	101	2273	459	0·55	0·23
II.	2 & 2A	750	417	2273	1265	0·68	0·38
III.	2	682·5	300	2273	300	0·33	0·41
IV.	—	353	30	2273	30	0·84	0·16

It will be seen that high ideal efficiency is as a rule accompanied by a high ratio of negative work to gross work. Cycle 4 is, however, an exception to the rule. The cycle has the highest ideal efficiency and the lowest ratio of negative work to gross work. As has been already pointed out, however, the efficiency which we could actually hope to obtain with this cycle would be very much below the ideal, and the cycle has other objections, as already stated.

Cycle I, Case 1, has a high ratio of negative work to gross work although the efficiency is the lowest. This is because all the heat is supplied to the gas at a comparatively low temperature.

As regards the Carnot cycle, an engine working on this cycle would have the same value for E as one working on Cycle I for the same values of t and t_c; and, if the isothermal expansion were carried far enough, it would (under ideal conditions) do the same work per cycle for the same amount of fluid, and have the same ratio of negative work to gross work. The maximum volume of the fluid would, however, be very much greater, and although this is not such a serious matter with a turbine as with a reciprocating engine it is nevertheless not a condition to be accepted without due recompense.

If an engine working on Cycle I has $T_1 = t_c$, then an engine working on the Carnot cycle with the same values of t and t_c, would require, in order to do the same work, to commence its adiabatic expansion at the point where the engine working on Cycle I leaves off. If p and P_1 on the Cycle I engine are atmospheric pressure, then on the Carnot cycle engine the whole of the adiabatic expansion would take place below atmospheric pressure. It is interesting to compare the Carnot cycle with other cycles, but it hardly seems useful in the present investigation to devote any more space to this.

To produce a gas turbine cheaply it would seem necessary to entirely avoid reciprocating parts and to be content with a low compression. Cycle I, Case I, would seem to lend itself to cheapness of construction and simplicity, but it might be advisable to reduce the compression at the expense of efficiency. A rotary pump could undertake the compression.

The power of a gas turbine could be effectively varied with an insignificant variation of speed by cutting out one or more of the nozzles or admission ports which admit the fluid to the turbine buckets or first set of buckets when several are employed in series, the fluid being passed through the acting ports or nozzles at a uniform pressure and with a uniform velocity. To enable the acting nozzles or admission ports, no matter how many may be in use, to deliver the fluid always in the same uniform manner, it will be necessary, if one flame supplies all the nozzles or admission ports, to control the fuel and air supplies to the flame in conjunction with the mechanism which cuts off the nozzles or admission ports. It will however be usually advisable to supply the air and fuel to the flame at a constant velocity and, although this could be done when one flame supplied a varying number of nozzles, this would involve complications; and it may therefore be found expedient to have a separate flame and a separate combustion chamber for each nozzle. This will however involve the necessity of igniting or extinguishing a flame for each change of power, and although this could be done automatically, it is objectionable. Much careful consideration will be required to determine which is the least evil to put up with and which course had better be taken.

One cannot compare the several cycles and estimate the actual efficiencies, etc., which one could expect to obtain in practice in anything like so satisfactory a manner as could be desired, without having more information obtained by experiment on the following three points:—

1. Losses in pneumatic compression to high pressures.
   (*a*) With reciprocating compressors.
   (*b*) With rotary compressors.
   (*c*) With a combination of reciprocating and rotary compressors.
2. Expansion of hot gases in divergent nozzles.
3. Radiation losses and transference of heat from gases to metals at high temperatures.

It would immensely aid the solving of the gas-turbine problem if a thorough set of experiments on these three points were made and the results published.

The Paper is illustrated by 22 figures in the letterpress.

On a Process for Operating Gas Turbines.

By F. MEINEKE.

Dingler's Polyt. Journal, Oct. 1st, 1904.

ALL endeavours so far made to design a gas turbine have been based on the working cycle of reciprocating gas-engines, a mixture of fuel and air being burned at constant volume. As, however, this process does not admit of continuous operation and the production of a constant pressure, both of which are necessary conditions for the rational working of a turbine, the author regards any design based on such a process as of little value. Combustion at constant volume further necessitates a closed chamber, and valves and igniters for periodical operation, so that those parts which are most liable to disorder are not eliminated. The author accordingly suggests producing the combustion at constant pressure in an open space, thus obtaining a continuous operation. The expansion of the gases would take place by converting their pressure into velocity in the nozzle of a gas turbine, which would have to differ from those of a steam turbine only by the provision of a cooling arrangement. The expansion would occur adiabatically but for the losses by friction and whirling; as a matter of fact, the entropy increases so that the co-

efficient of expansion in the expansion law $p\,v^{\kappa} = \text{const.}$ becomes smaller than k (being the co-efficient of the specific heat at constant volume by the specific heat at constant pressure). This departure is, however, not taken into account. The compression of the fresh mixture will also occur practically adiabatically, so that the cycle of the gas turbine would consist of two operations at constant pressure, viz., supply and discharge of heat, and two adiabatic alterations, viz., expansion and compression. Similar cycles have, it is true, been previously made use of in connection with open hot-air engines, but no satisfactory efficiency has yet been obtained in that way. If the expansion takes place in a nozzle capable of being readily cooled, instead of in a cylinder, the gases will enter the turbine at the temperature obtaining at the end of the expansion; the temperature differences between which the cycle is performed, may thus be considerably increased and the efficiency improved. As regards the realisation of this process, this requires in the first place a combustion-chamber consisting of a cylindrical vessel, lined with fire-resisting material, the capacity of which is so designed that a given volume of air and gas is allowed to be burnt there. The burnt mixture, in order to avoid any heat losses, follows a path as short as possible to the turbine nozzles, where expansion accompanied by decrease in temperature occurs. After traversing the running wheel, the gases are made to issue into the open at the temperature T_4 (Fig. 1), if the whole process be carried out above atmospheric pressure. As, however, the resistance of the running wheel, which represents a large portion of the aggregate loss of energy increases with the density of the air, it is better to allow the gases to expand below atmospheric pressure, when the exhaust gases, instead of issuing into the open air should be cooled down to T_2, at constant pressure, by means of a cooling coil, to be compressed afterwards to atmospheric pressure, thereby increasing the temperature to T_5. The compression work from $p_2\ v_2$ to $p_3\ v_3$ is accordingly separated into two parts; namely, first, the compression to p_5 (atmospheric pressure) v_5; and second, the compression to $p_3\ v_3$. Part of the heat given off by the exhaust gases is used for preheating the combustion air up to the temperature T_5. Instead of using a reciprocating air-compressor, a rotary compressor mounted on the turbine shaft should be employed. It should not be difficult to obtain very high pressure differences by inverting the process that takes place in a turbine. Care has to be taken that the air be conveyed to the running wheel at the velocity at which it would leave it in the case of the machine acting as turbine, when the air will issue from the running wheel at a very high speed to be compressed by convenient guiding vanes or nozzles. The air heated to T_3 by compression is conveyed to the combustion chamber (Fig. 2), passing first through the surrounding space before entering the central chamber. The fuel is fed in at the top, the design of which would vary according to the solid, liquid or gaseous condition of the fuel. The nozzles of the turbine might be conveniently cooled by boiling oil, as water would withdraw too great a quantity of heat. In addition to the energy losses in the turbine compressors, the heat losses by conduction and radiation are to be accounted for; there is further a loss due to the cycle not being absolutely reversible, as supposed. The estimates of the author give the results recorded in the following table, where η_m is the efficiency of the turbine and compressor and η the total efficiency:—

η_m	η%	Heat consumption per h.p. in calories.
0·90	36·5	1750
0·85	29·2	2180
0·80	22·0	2890
0·75	14·0	4550
0·70	5·75	11100
0·668	0	∞

From this table the strong decrease of the heat consumption with increasing efficiency of the turbine is inferred.

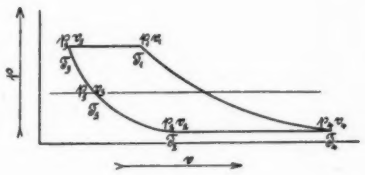


FIG. 1.

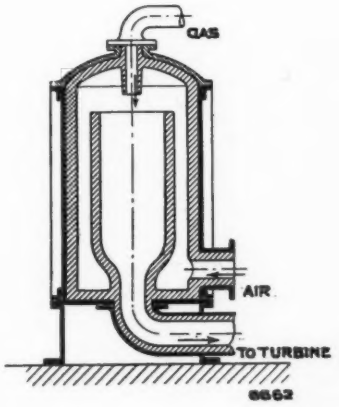


FIG. 2.

A Simple Dynamometer.

By W. J. SPIRO.

The School of Mines Quarterly. Vol. xxv, No. 4.

When a factory or manufacturing plant is located in a city, where ground-rent is high, it is necessary that it cover the least practicable area, the necessary amount of floor-space being secured by building it two or more storeys in height. This introduces the problem of transmitting the motive-power needed to drive the various machines and tools from one floor to another, with the least possible loss and at the lowest possible expense.

There is a method of power transmission consisting of a vertical shaft extending from basement to roof, which is driven by belt from the engine, and from which quarter-turn belts at each floor drive the several line-shafts. This system possesses many advantages, from the points of view of economy, safety and convenience, and an investigation of its merits, with special reference to the determination of the energy necessary to drive the vertical shaft under all conditions of load, should lead to useful results. It is the object of the paper to present the results of such a test, made on a shaft of a manufacturing company transmitting 50 h.p. to the six storeys of the building. A sketch of the plant is given in Fig. 1.

In order to perform this test, a special transmission dynamometer was designed and constructed, and was used to measure: (1) the power to drive the vertical shaft alone; (2) the power used up in the quarter-turn belts; and (3) the power necessary to drive the entire transmission system of vertical shaft, line-shafts and belts.

Before entering upon the discussion of the test itself, it will be well to consider in detail the dynamometer referred to above, as upon this depend the accuracy and reliability of all the results obtained.

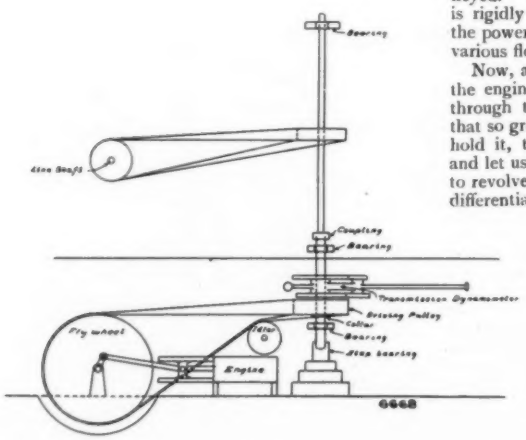


FIG. 1.

The main point in view in designing the instrument was to produce an apparatus which would do the work required of it without in any way interfering with the operations of the plant to be tested, and without requiring any extensive alterations to the latter. Referring to Fig. 2, *S* is the vertical shaft, normally driven by a pulley (not shown) over which passes a quarter-turn belt from the engine fly-wheel. For the purpose of this test this pulley was loosened on the shaft and connected by straps to gear *B*, which also revolves loosely on the shaft, and which will hereafter be called the driving gear. *E* is an arm revolving loosely on shaft *S*, and carrying at its other extremity the arbor *M*, to which are keyed the pinions *C* and *D*. The gear *A*, which meshes with the pinion *C*, and will be called the driven gear, is clamped rigidly to the vertical shaft *S*. Into the extremity of the arm *E* is screwed a length of gas-pipe *F*, carrying a ring *G*, to which is attached one end of a spring-balance *T*, the other end of which is rigidly attached to a beam. The other end of the arm *E* carries a shorter length of pipe, on which slides the leaden ball *H*. This ball may be fastened by a set-screw at any point of the pipe on which it slides, and its purpose is to counterbalance the weight of the arm *E*, the pinions *C* and *D* and the pipe *F*.

The operation of the dynamometer is as follows: The power of the engine is transmitted by the quarter-turn belt to the driving-pulley, and thence to the driving gear *B*. This gear meshes with and drives the pinion *D*, which in turn drives the pinion *C* through the arbor *M*, to which both are keyed. The pinion *C* drives the gear *A*, which is rigidly connected to the shaft *S*, from which the power is taken off by quarter-turn belts at the various floors.

Now, as long as the arm *E* remains stationary, the engine will drive the vertical shaft positively through the train of gears. But let us suppose that so great a load is applied to the shaft *S* as to hold it, together with the gear *A*, immovable, and let us further suppose that the arm *E* is free to revolve about the shaft *S*. Then, owing to the differential action resulting from the difference in size of the gears *A* and *B* and the pinions *C* and *D*, the entire power of the engine will be consumed in rotating the arm *E* about its shaft. To prove this, let us suppose that gear *B* has 90, *D* 60, *C* 50, and *A* 100 teeth. Then, when gear *B* makes one revolution, it will have revolved pinion *D* through 90/60 = $1\frac{1}{2}$ revolutions. Pinion *C* will, of course, have made $1\frac{1}{2}$ turns also, which in its case is equivalent to $1\frac{1}{2} \times 50 = 75$ teeth; and since gear *A* is stationary, this will have

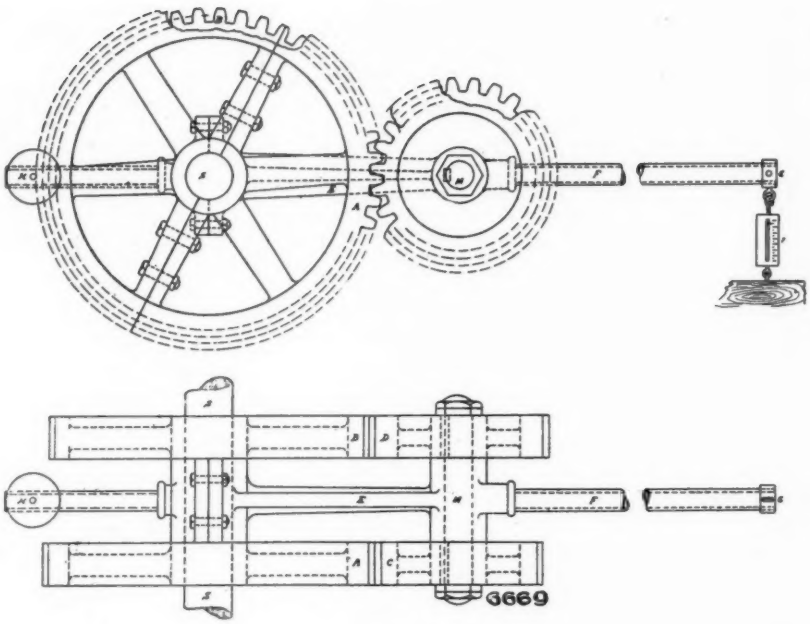


FIG. 2.

caused the arm E and its pinions to rotate about S through 75 teeth of A, which is equal to $\frac{75}{100}$ or $\frac{3}{4}$ of a revolution. Thus, for every revolution of the driving gear the arm E will revolve $\frac{3}{4}$ of a turn about S.

Now, if we assume the normal working conditions, *i.e.*, S carrying its normal load, and motion of E resisted by the action of the spring-balance T, then it will be evident that the power applied at B may be expended in either of two ways: it may rotate the shaft S, thus carrying the machinery load, or it may revolve the arm E about that shaft against the resistance of the spring-balance T. Since any force always chooses the path of least resistance, the engine will choose that one of the two alternatives which demands the expenditure of the least amount of power. What will actually happen is this: The rotation of the gear B will cause the arm E to revolve until the resistance of the spring-balance is just equal to the resistance to motion of the shaft S. Further revolution of B will then cause revolution of S, T remaining in a position corresponding to the load on S. The balance T will therefore measure the pull necessary to revolve the shaft S; and since we know the effective length of the arm E and the number of revolutions of B per minute, we may calculate the horse-power input necessary to revolve the shaft together with its load.

The numbers of teeth in the gears and pinions are as follows: Gear A, 48 teeth; gear B, 46 teeth; pinion C, 24 teeth; and pinion D, 26 teeth. Now if A be held rigid, and arm E be revolved about shaft S, then when it has made one complete revolution the pinion C will have made $48/24 = 2$ revolutions, as will also the pinion D. As this latter pinion has 26 teeth, it will, during a revolution of the arm E, move over 52 teeth of B. But since B has only 46 teeth, it will have to move $52 - 46 = 6$ teeth in the direction opposite to that of E's rotation in order that the above conditions may hold. Thus, whenever B gains 6 teeth, or $\frac{6}{46}$ of a revolution on A, the arm E will make one complete revolution about S. From this it follows that E revolves with but $\frac{6}{46}$ of the force, or pull, which tends to cause revolution of B. Thus, if we measure the pull at the balance T, and multiply this by the effective length of the arm E-F, we must multiply this product by $\frac{46}{6}$ or $7\frac{2}{3}$ in order to get the moment of the gear B. Multiplying this by the number of revolutions per minute made by B, and by 2π, and dividing by 33,000, we shall have the h.p. input for any load. This may be otherwise stated as follows: $HP = 2\pi PLNC/33{,}000 = PN2\pi LC/33{,}000$, where $C = 7\frac{2}{3}$.

For any given length of arm L, the product $2\pi LC/33{,}000$ is constant, and in order to find the h.p. input we need only multiply the product of

the balance-reading and the revolutions per minute by this constant. The process will be still further facilitated if the constant be some even fraction, such as .01. Let us see what length of the arm E would make the constant take this value. We will have $2\pi LC/33{,}000 = .01$, whence, solving for L, we have $L = 6.8506$ ft., or 6 ft. 10.2 ins. Thus if we fix the ring G (Fig. 2) at 6 ft. 10 ins. from the centre of the shaft S, then to find the h.p. input at any load we need only multiply the balance-reading by the revolutions per minute and point off two places. Similarly if we make $L = 3$ ft. 5.1 ins., then the constant will be $\frac{1}{200}$, and if $L = 2$ ft. 3.36 ins. the constant is $\frac{1}{300}$. Marks representing these lengths of lever-arm are accordingly made on the pipe F, and the ring G may be brought to any of these marks, and there fastened by means of a set- screw.

The various parts of the dynamometer having been completed and assembled, the instrument was placed in position on the vertical shaft, the weight of its parts being supported by a collar fixed on the shaft. Arms (not shown in the drawing) extended upward from the gear B, engaging with the spokes of the driving-pulley, while similar arms extending from gear A engaged with the spokes of another pulley, loose on the shaft, to which the band of the prony brake was applied.

The spring-balances of the dynamometer and the prony brake having been calibrated by means of weights, and being found sensibly correct, the calibration of the dynamometer itself was next undertaken. For this purpose gear A was not clamped to the vertical shaft, but was allowed to revolve loosely thereon, liners being put between its two halves to accomplish this. The band of the prony brake being loose, the engine was then started, whereupon the arm of the dynamometer swung around in the opposite direction to that in which it was expected to turn. It was soon seen that, there being no load on the gear A, the friction of the various parts was carrying the entire arm around in the same direction as that in which the driving-pulley revolved. The spring-balance being removed to the other side of the arm, and the engine being again started and brought up to speed, it was seen that the friction produced a practically constant pull of 10.1 lbs. on the balance at a radius of 2 ft. 3.36 ins., corresponding to pulls of 6.72 lbs. and 3.36 lbs. at radii of 3 ft. 5.1 ins. and 6 ft. 10.2 ins. respectively. If we regard pulls in this direction as negative, then it is evident that we must subtract from the scale-readings at any load the constant friction-pull above determined, in order to obtain the actual pull due to the load.

Proceeding thus, the prony brake was now put into service, and simultaneous readings taken of the brake and dynamometer scales, from which it was found that the friction-loss in the dynamometer increased slightly with increase of load.

The dynamometer having been calibrated, a test of the power consumed by the vertical shaft at various loads was next in order. For this purpose the gear A was clamped tight to the vertical shaft, as was also the pulley on which worked the prony brake. Load was now applied to the latter, and was transmitted through the vertical shaft to the dynamometer, where it was measured. The readings and results showed that the loss in the shaft is nearly constant at all loads, and amounts to only about 1¼ h.p.

The next and last part of the test consisted in ascertaining the power required to drive the belts and shafting forming the power-transmission system of the factory. The prony brake was removed, and the quarter-turn belts at the various floors were put on one by one, the load due to each belt and line-shaft being measured at the dynamometer. The results given show that the power required to drive the transmissive machinery constitutes only about 20 per cent. of the total power consumption, proving that the vertical shaft transmission involves a saving in power of from 5 to 20 per cent. over the common belt-transmission.

The dynamometer is, of course, bored out to operate on a $3\frac{7}{16}$-in. shaft, but if a set of bushings be made for the gears and arm it might be used equally well on smaller shafts. If gear A be made the driver, instead of gear B, then the arm F will always revolve in the same direction, which will make it unnecessary to reverse the position of the spring-balance during the test.

This transmission dynamometer should prove useful in making tests on various types of machine-tools to determine accurately their power consumption as well as to find the losses in transmission systems, the relative efficiencies of rope and belt drives, etc. The fact that it can be operated on a line-shaft without change or injury to the latter should make it useful for making tests in factories up to the limit of its capacity (about 100 h.p.).

The Modern Telephone.

By S. P. GRACE.

Lecture before the Electric Club, Pittsburg, Pennsylvania.

To understand clearly the electrical and mechanical principles made use of in the modern telephone system, it is first necessary to acquaint ourselves with the physical laws underlying speech. It is well known that sound has its origin in the vibration of the molecules of the air, which alternately give rise to atmospheric condensations and rarefactions; *i.e.*, changes of pressure.

Sound may be divided into three general characteristics, loudness, pitch and quality. One sound may be louder than another, due to a greater amplitude of vibration of the body producing the sound, which therefore produces greater condensations and rarefactions in the atmosphere. Again, two sounds may be of the same loudness, but of a different pitch, or, technically speaking, a different

number of vibrations per second. As an example of pitch, suppose we strike the key C in adjacent octaves on a piano. The number of vibrations per second of C in the higher octave is just twice that of C in the lower octave.

The last characteristic of sound, that of quality, is, perhaps, the most important. Very few sounds in nature are fundamentals. Practically all musical instruments and the human voice in particular give out sounds composed of partial tones, or overtones, in combination with the fundamental tone. As a familiar example, consider a vibrating string stretched between two points. By plucking the string in the centre, it is possible to make the string vibrate as a whole and thus give a fundamental tone of a pitch depending upon how tightly the string was stretched. The tighter the string is stretched the greater will be the number of vibrations per second, and the higher the key of the note produced. Should the string be plucked away from the centre it will be thrown into sectional vibrations. If the string vibrates in two parts, we would then have the fundamental note combined with the second overtone; if in four parts, with the fourth overtone, and so on.

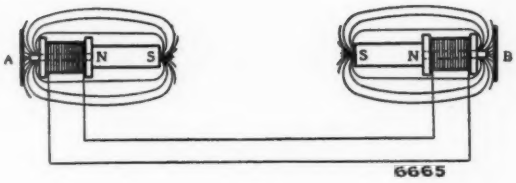


FIG. 1.

In general, then, the quality of a sound depends upon the number, the intensity and the position of the overtones. It is this arrangement of the overtones which makes the same note on a violin different from the same note on a piano, a guitar, or a mandolin. The overtones are also responsible for the differences between human voices. Because of the variety and number of the overtones the sounds produced by the vocal chords are of a very complex character, and the resulting air waves have vibration rates ranging all the way from 200 to 5,000 per sec. To transmit the sound waves of the human voice electrically to a distance is at once seen to present many serious problems. Obviously an electric current must be capable of changing and reversing many hundreds and even thousands of times per second. It was not until 1876 that Alexander Graham Bell succeeded in making one diaphragm perform exactly the same evolutions as a diaphragm located many feet away, and which was thrown into vibration by means of a human voice spoken against it. Bell clearly saw that if speech was to be transmitted electrically, it must be done by a current which was undulatory in character, and that the circuit must never be electrically broken. The telephone of Bell was delightfully simple; it consisted merely of a magnet provided with an extension iron pole-piece, about which piece was wrapped a few turns of insulated wire. The placing of a thin iron diaphragm in front of the pole-piece and separated from it by a small air-gap completed his invention.

Bell's telephone will act either as a transmitter or a receiver. Fig. 1 is a skeleton diagram of Bell's original telephone, and, in fact, the telephone receiver exists to-day practically as designed by Bell twenty-five years ago. If the diaphragm of *A* be spoken against, it will be thrown into vibration in nearly exact accordance with the condensations and rarefactions of the air waves striking it. The diaphragm being made of iron will therefore, by its change of distance from the pole-piece, permit a greater or lesser flow of magnetic force through the coil of wire on the pole-piece; because by changing the field of magnetic force through a closed coil there is set up in it electrical currents which are directly proportional to the rate of change of magnetic force. Suppose the wires from *A* are connected into a similar instrument at *B*. The varying current from *A* traversing the coil at instrument *B* will increase or decrease the magnetic field of instrument *B*, and will therefore vary the pull upon its diaphragm. Obviously diaphragm *B* will be thrown into vibration, and its vibrations will be practically identical with the vibrations of diaphragm *A*. Since the vibrations of diaphragm *A* correspond with the sound waves produced by the vocal chords of the person speaking at *A*, similar sound waves will be set up by the diaphragm at *B*. These, reaching the ear of the observer at *B*, will actuate his ear-drum, and the acoustic nerves will convey to his brain the impression of the sound waves as originally spoken at *A*.

The original Bell instrument, though transmitting and receiving speech with remarkable clearness, was still inadequate for use as a transmitter, because of the faintness of the transmission. Bell's instrument as a receiver is one of the most remarkably delicate instruments known to electrica science. This may be fully realised from the statement that one two-millionth of an ampere will produce an audible sound in a Bell telephone receiver.

It was only a short time until Berliner and Edison evolved a transmitter which would act, so to speak, as a valve on a source of electrical energy. When Bell's instrument is used as a transmitter, the energy of the sound waves conveyed to the diaphragm produces the electrical energy in the coil around the pole-piece. It is obvious that the amount of electrical energy cannot exceed the mechanical energy of the vibrating diaphragm. The Berliner and Edison transmitter depends upon the variable resistance of two bodies placed loosely in contact, when subjected to changes of pressure. The most successful forms of transmitters make use of the variable resistances between two carbon electrodes separated by means of carbon granules. It has been found that if one of these electrodes be

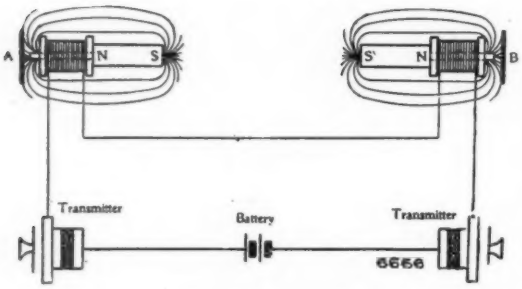


FIG. 2.

connected to a diaphragm which is spoken against, the resistance of the carbon will vary in accordance with the pressure upon the electrodes, and therefore with the condensations and rarefactions in the air waves striking the diaphragm. If there is a current of electricity flowing through this contact, it is clear that the current will be varied in exact accordance with the sound waves striking the diaphragm.

In Fig. 2 is shown two transmitters and two receivers connected serially in a circuit containing a battery. When either transmitter is spoken into, a variable current is produced in the circuit which will produce a varying magnetic field in both receivers, and force their diaphragms into vibration. These receiver diaphragms will perform the same evolutions as the transmitter diaphragm which is spoken against, and will therefore reproduce speech. That the diaphragms of both the transmitters and receivers are capable of taking up the minute overtones of the human voice is truly remarkable. That this is so is conclusively proven by the fact that familiar voices are at once recognised in the telephone, which would not be the case if the number, intensity and position of the overtones were not practically the same at the receiving end of the line as at the transmitting end. The overtones of some letters are very numerous and complicated, and are very difficult to transmit electrically. This is particularly true of the letter S and a number of other consonants. Strictly speaking, the received sounds have not exactly the same quality as the transmitted sounds, but they are sufficiently clear for practical purposes.

It has been very often asked why a permanent magnet is used in a telephone receiver. One reason is that if no permanent magnet be used the received sounds will be an octave above the sounds at the transmitting end. It is also because the amount of movement of the diaphragm for a small change of current is within practical limits proportional to the strength of the permanent magnetic field. Suppose in a telephone-receiver that H equals the initial permanent magnetic force. Then the force acting upon the diaphragm is proportional to the square of the magnetisation of H^2. If the magnetisation increases a small amount h, due to a slight change of current in the magnetising coil, the pull on the diaphragm will be $(H + h)^2$. The difference or change in pull will therefore be $(H + h)^2 - H^2 = 2Hh + h^2$. From this formula it is evident that the pull on the diaphragm will increase without limit as H, or the initial magnetisation, is increased. The practical limit, however, is the degree of magnetisation at which the iron in the diaphragm becomes saturated.

The secret of a good transmitter lies in the arrangement and treatment of the carbon electrodes and carbon granules. In designing the solid back transmitter used by the Bell telephone companies, many years of careful laboratory experimentation were required before a thoroughly efficient and durable grade of carbon was produced. For transmitter use I may say that a carbon of almost glass hardness and extreme durability is required.

Electric light and power engineers very rarely have to deal with frequencies exceeding 125 cycles per second. To the telephone engineer who deals in frequencies of 300 to 5,000 per second, 125 cycles appear ridiculously small. While the telephone currents are not of large magnitude it is readily conceived that because of their high frequency the distorting and attenuating effects of self-induction and capacity are very marked. It is imperative, therefore, on all long aerial lines and cable lines that the distributed capacity be a minimum. Great care must be exercised not to place impedance in improper places in a telephone circuit, for if this is done, serious choking effects may be produced on the telephone current, or if the line is so long that the transmission assumes a wave form, there may be serious reflections of current from improperly placed impedance coils. Telephone engineers dealt with capacity and impedance long before their importance was realised by electric light and power engineers,

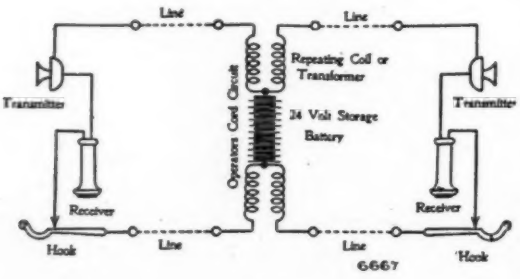


FIG. 3.

and were obliged to develop apparatus and lines which would work under these severe conditions of high frequency. The most recent work on the subject has been done by Dr. Pupin, who has shown how largely to counteract the effects of disturbed capacity by means of distributed self-inductance. In Pupin's system, impedance coils, known as load coils, are placed at intervals in the line depending upon the wave length. The telephone receiver and transmitter which I have described would be of little value in the business world if some means were not provided so that conversations could be carried on between any two instruments in a system containing thousands of telephones. The invention of the telephone receiver and transmitter started the march of invention of central office switching devices.

Until the last decade the systems of switching were, to a great extent, crude, and were rapidly proving themselves incapable of handling the vast volume of traffic which they were called upon to carry. About seven years ago the old magneto-type switchboards were abandoned, and were replaced by the common battery systems of to-day. The three great advantages of the common battery system may be summed up as: first, improved quality of service to the public; second, increased speed of operation; third, reduction of maintenance.

Of the different common battery systems, the repeating coil system is the one most generally used. This is shown diagrammatically in Fig. 3. One large storage battery is used as a source of current for all the lines. Two telephone lines are connected by two flexible cords, in which are placed repeating coils which are simply transformers having the same number of turns in primary and secondary coils. The two lines are connected to the main battery as shown. It is apparent that any change of current in either telephone circuit, caused by a variation of the transmitter resistance, will, through the action of the transformer, be reproduced in the other or receiving telephone circuit. Any number of lines, with their repeating coils, may be connected to the one battery with no danger of "cross-talk" from one line to another. "Cross-talk" would be caused if the variable current in one repeating coil caused a change in the current in another coil, but on account of the low resistance of the battery this is not possible.

Fig. 4 represents the complete connections between two subscribers through a repeating-coil, common battery switchboard. At the left of the diagram is shown the connections of a subscriber's telephone. The apparatus in the telephone consists of a transmitter, a receiver, an induction coil, a condenser, a polarised bell, and a hook switch. The functions of the transmitter and receiver have already been explained. The induction coil, which is nothing more than a small transformer, is used so that the receiver will be out of the line circuit, which includes the main battery. It has been found that direct current through the receiver is liable to demagnetise the permanent magnet and to injure the diaphragm. The condenser is placed in the instrument in

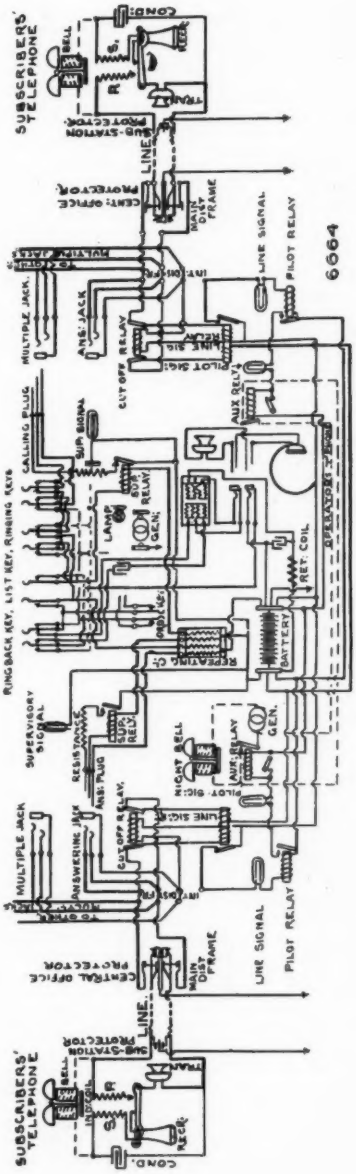


FIG. 4.

order that the two sides of the line circuit may be kept open to the direct current which tries to flow from the central office main battery, thus preventing the operation of the line signal relay at central. The operator can ring the polarised bell at the subscriber's telephone through the two microfarad condenser, since for ringing purposes single-phase alternating current is used, which passes readily through the condenser.

The connecting cables are made up of twisted pair wires insulated with spiral wrappings of paper, and the whole enclosed in a continuous lead sheath. As many as 600 pairs of wires are sometimes placed in a single cable. The reason for using a paper insulated and lead covered cable is, first, because of its low cost, and, second, that with a paper insulation we obtain a very low mutual static capacity of each pair of wires. This low capacity is necessary in order not to seriously attenuate or distort the high-frequency telephone currents traversing over the circuit.

On entering the central office the cables are ended in the main distributing frame. From this the pairs of wires pass through arresters or protectors to the intermediate frame and then to the switchboard. Each telephone line appears on the switchboard in a switch which is known as an answering jack. In addition, the line appears in what is known as the multiple jacks in every third position of the entire switchboard. The purpose of the multiple jacks is to enable any operator to plug in any line. This completes the connection of a subscriber's line to the switchboard. The remaining connections shown in Fig. 4 are for the connecting plugs containing the repeating coils, the operator's telephone and the signals.

It will be seen that in the switchboard three wires and three jack and plug contacts are used for each line. Two of these wires are for the talking circuit, the third being a signalling or controlling circuit for the operation of the various relays, signal lamps, etc., which are necessary for a proper supervision of the connection.

When the subscriber removes his receiver from the hook, the rising of the hook will close the contacts of the switch and close the line at the subscriber's station through the transmitter, the primary of the induction coil, and the hook switch contacts. The line being now closed will permit of current flowing through it from the main battery, and since the line signal relay is inserted serially in this circuit at the central office its armature will be attracted, which, closing a secondary circuit, will cause the lighting of the line lamp in the face of the switchboard adjacent to the answering jack of the subscriber who has called. The lighting of the line lamp is practically simultaneous with the removing of the receiver from the hook.

As previously stated the operator is provided with a number of pairs of double-ended plugs and cords which are so wired as to permit of the connection of two subscribers' lines. Upon seeing the line lamp light the operator will pick up a plug connected to one of her answering cords and insert it into the answering jack associated with the lighted line lamp. The inserting of the plug in the answering jack causes a flow of current in the controlling, or third wire circuit. It will be noticed that this current in the third wire flows through the cut-off relays, thus causing its armature to attract and open the circuit through the line lamp. This causes the extinguishment of the line lamp automatically. As the subscriber has his receiver off the hook the line is closed at the telephone, and as soon as the plug is fully inserted the line current, which the instant before was broken by the cut-off relay, is re-established through one-half of the repeating coil and the cord circuit. The current flowing in the main line will cause the operation of the 10-ohm supervisory relay which is placed in series with one side of the cord circuit. This relay being operated will connect the 40-ohm shunt around the supervisory lamp, which, therefore, will not receive sufficient current to be illuminated. The operator will now depress her listening key, which will connect her telephone set in parallel with a cord circuit which is connected to the sub criber's line. She will now speak into her transmitter and obtain from the subscriber the number wanted. The operator's set is practically the same as an ordinary telephone, but arranged with switching devices so that it may be connected to the various cord circuits.

Upon receiving the number wanted the operator will take the calling plug of the same pair of cords, and reaching to the multiple jack of that number will touch the sleeve of the jack with the tip of the plug. In Fig. 4 the called subscriber's line is represented at the right of the diagram. If the subscriber's line wanted is plugged at some other part of the board the potential of the sleeves of all the multiple jacks of that line will be raised above the earth, and under this condition if the sleeves of any of these multiple jacks are touched by the tip of a plug there will be a rush of current through the cord circuit, which will cause a click in the operator's ear and thus inform her that the line is "busy." If the line wanted is not busy, which would be indicated by silence when the tip of the plug is touched to the sleeve of the jack, the operator will fully insert the plug and depress one of her ringing keys connected to the cord. This will send a single-phase alternating current over the line of the called subscriber through the condenser and bell located in his telephone. The ringing of the bell will summon the called subscriber to his telephone.

The insertion of the calling plug has operated the cut-off relay and will prevent the called subscriber from flashing his line lamp when he answers the call. However, until the called subscriber answers, the supervisory relay connected with the calling plug will not be operated, and therefore no shunt will be around the supervisory lamp. The supervisory lamp will thus be illuminated, and will clearly indicate to the operator that the called subscriber has not answered. She will therefore keep on ringing until he answers. or finally send back a "don't answer" report to the calling subscriber. Should he answer, current will flow through both sides of the line from the right-hand half of the repeating

coil and will operate the supervisory relay, which will shunt the supervisory lamp and cause it to be extinguished. The connection now being completely established the two subscribers will converse with each other on the principles already described. When the conversation is finished and both subscribers hang up their receivers both lines will be opened at the hook contacts and the supervisory relays will release. This will remove the shunt from around the supervisory lamps and cause them to be illuminated. The lighting of the supervisory lamps connected with the cord circuit indicates to the operator that the conversation is finished. She will then remove the plugs from both the answering jack and the multiple jack, and all circuits will return to normal and all lamps will be extinguished.

The circuits herein described show the connections which take place for local connections between two subscribers connected with the same office. In a modern telephone system in a large city this is only one of the many hundreds of circuit combinations which must be used. There must be provided suitable trunks and signals between relay offices for local connections and for toll connections, trunks between long-distance boards and local boards, and order wire circuits. So many are the circuit combinations that a complete description of them is practically impossible, and would be out of place in a paper of this character.

70,000-Volt Direct-Current Tests made at Geneva, Switzerland.

By B. F. HIRSCHAUER.

Electrical Review, New York.

THE question of the transport of force to great distances is becoming more and more important, seeing that the applications of current for lighting and traction are constantly increasing; and, on the other hand, the hydraulic forces which are situated near the place of consumption are being successively utilised, so that it becomes necessary to go to greater distances to find new ones which can be used. As an example of these conditions in Europe, it may be mentioned that the city of Zurich now has a project on foot for using hydraulic power which lies no less than 80 miles from the centre of distribution. In France, where the use of hydraulic power is constantly on the increase, it is proposed to secure a supply for Paris which will be brought from a distance of 250 miles.

In this connection, the new experiments with high-voltage distribution on the direct-current system which have been carried out at Geneva under the direction of M. Réné Thury, the well-known engineer, are of special interest. M. Thury is the champion of the high-voltage direct-current system, and he seems to have proved that his ideas are correct by the successful operation of the St. Maurice-Lausanne high-tension line. This plant is one of the largest as well as the most interesting in Switzerland. The line uses no less than 23,000 volts direct current, with a constant current of 150 ampères. This high voltage is obtained by coupling several direct-current dynamos in series. In order to test the high-tension lines the Compagnie de l'Industrie Electrique decided to build a machine which should produce 23,000 volts directly. The problem was not an easy one, owing to the numerous difficulties which were met with in producing such a high voltage. Up to the present the highest tensions which have been obtained with direct current reach 10,000 volts. M. Thury first built a 23,000-volt machine, and as this proved a success he proceeded to construct two others of somewhat higher voltage. Then, by connecting these three machines in series, he was able to reach the remarkably high tension of 70,000 volts direct current. It might be expected that such a high voltage would give rise to some interesting tests, and such was the case. M. Thury wished to find what would be the limiting voltage which could be used on a high-tension line in practical work. Seeing that the St. Maurice line has no difficulty with 23,000 volts, and thus distributes a large amount of power to Lausanne, there seemed to be no reason why this voltage could not be considerably increased. It is naturally a question of insulation for the most part. Accordingly, the first series of tests were made in order to find out how the standard forms of line insulators would behave towards 70,000 volts direct current, and especially to compare the latter with alternating current of high voltage. As is shown by the present results, the direct current proves much superior to alternating current in regard to porcelain insulators and in general to different kinds of insulating material.

The type of machine employed is a bipolar dynamo, which has the external appearance of an alternator with radiating poles. The field is built of laminated iron, and revolves inside a ring which forms the armature. The latter is thus fixed and has 48 coils, which are inserted in the same number of slots around the periphery. The coils are insulated by paper coated with a special insulating compound. Each simple coil comprises 500 turns of copper wire 0·5 mm. gauge silk-covered. The whole armature thus contains 24,000 armature turns, whose resistance when the machine is running is 700 ohms. It is capable of delivering one ampère on a normal run.

The commutator of the 23,000-volt machine is made up of 96 segments, which are separated by air spaces. It is fixed contrary to the commutator of an ordinary dynamo. The current is taken from it by two small metallic brushes which run upon the inner surface of the commutator. As it was feared that arcs would be formed between the segments, seeing that there is 500 volts between each of them, a set of condensers are placed in shunt between each of the commutator segments. This arrangement proved highly satisfactory, and

was an important factor in obtaining the desired results from these machines.

The exciting current is furnished by a small separate dynamo in the same way as for an alternator. The maximum exciting current was calculated at 14 ampères and 80 volts, but in practice it suffices to use but 8 ampères in order to obtain 23,000 volts from the dynamo at the normal rate of 600 revolutions per minute. The usual voltage which the dynamo is designed to give is from 18,000 to 20,000 volts, but it can easily be run for a few minutes at 23,000 volts, which is the maximum needed for these tests.

According to this, it seems that there would be no difficulty in building a machine for much higher voltages. It is a question of dimensions and also of cost. It was preferred to use several machines of this type placed in series, as this allowed of reaching the highest possible voltages without any other precaution than that of insulating from the ground. This latter point was obtained without any difficulty. In the present type of machine the interior bore of the armature is 58 cm. (23·3 ins.). The peripheral speed at 600 revolutions per minute is therefore 18·22 m. per second, which is a comparatively low rate, seeing that as high speeds as 50 m. are sometimes reached.

To give an idea of the tensions which are necessary for an economical transmission of power, it may be said that if we admit the use of direct-current, allowing a loss of 10 per cent. in the line and a weight of copper of 30 kg. (66 lbs.) per electric h.p. received from the line, an initial tension of 4,200 volts will be needed for 10 kilos. distance (6 mls.), 42,000 volts for 100 kilos. (60 mls.). and 42,000 volts for 1,000 kilos. (600 mls.). The use of the earth as a conductor allows of doubling these distances for the same voltage, loss and weight of copper, or to reduce the voltage to one-half. On the contrary, the use of alternating current reduces these distances, owing to secondary phenomena which increase the loss in the line.

It became, therefore, of great interest to find out whether the advantages due to the use of direct current held good at high voltages. Seeing that no conclusive experiments had as yet been made beyond 25,000 volts, it might be asked whether some unexpected phenomena would not show themselves when this tension should be doubled or tripled in value, and whether the critical point of voltage which was practicable for industrial use would not be reached sooner than was imagined. In order to make the experiments at a much higher voltage than had been heretofore used the three special dynamos were coupled in series. As each of the machines could give one ampère as a maximum current, from 60 to 70 kilowatts was obtained from the combination, and this was a much greater power than was really needed for the experiments.

These tests were made especially to find how the different kinds of insulators would behave towards direct current compared with alternating current at these high voltages.

The experiments show the possibility of some new and very interesting applications of direct current to several modern problems, such as aërial telegraphy and the manufacture of nitrogenous products from the air.

To give a term of comparison, alternating current was used, which was produced by a special alternator. This is a machine of 75 kilowatts with revolving armature. The fixed field has six poles, and the speed was kept regular at 1,000 revolutions per minute. This gave a frequency of 50 cycles. The armature is of the smooth drawn type, with the flat coils placed on the surface and held by binding wire. The field poles covered two-thirds of the circumference. The electromotive-force curve was taken by a revolving contact device placed on the end of the shaft. As will be noticed in the diagram Fig. 1, this curve is flattened at its summit, so that the maximum electro-motive force, in place of being $\sqrt{2}$ × the mean electromotive force (as in a sinusoid), is really only 1·255.

From the standpoint of insulation tests this curve is extremely favourable to the alternating current. The sparking distances are reduced to a minimum, and the insulators resist much better at high voltages than with the ordinary alternating currents which are used in practice. In order to verify this, the curve was altered in shape by introducing a capacity into the circuit, and the results were conclusive. The sparking distances increased in a very considerable proportion. All the tests mentioned below were carried on with the direct use of the above wave without using such condensers. The variations of alternating voltage were obtained by regulating the exciting current and varying the ratio of the secondary of a raising transformer. For the direct current the voltage was varied by using from one to three of the generators, and by regulating the field excitation. The direct-current, it may be remarked, cannot be considered as absolutely continuous on account of the somewhat small number of commutator bars (96 segments), and from the fact that the armature coils are lodged in the grooves of a Paccinotti ring, which increases the self-induction and tends to give a wave form to the current. However, it is not probable that the effect of such small waves is appreciable in this case.

In spite of the above conditions, which are unfavourable for the direct-current and favourable

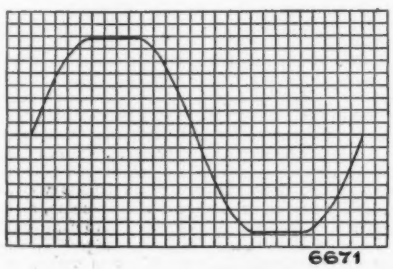
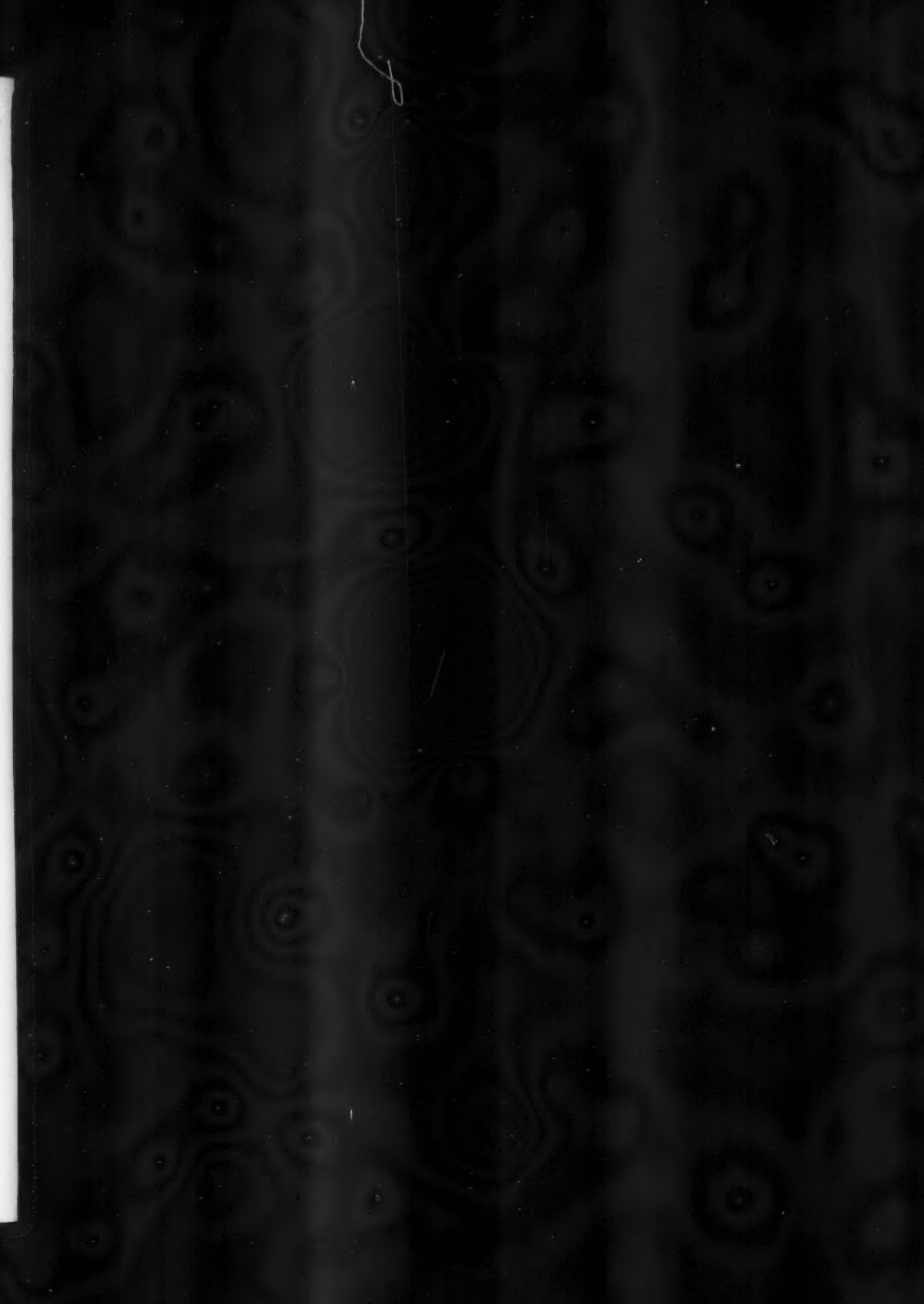


FIG. 1.—ALTERNATING CURRENT WAVE USED AT GENEVA TESTS.



for the alternating, the final results are clearly in favour of the direct-current. All the insulators, without exception, resisted much higher voltages for continuous-current than for alternating-current, which was to be foreseen. The same is true for all the insulating bodies which were pierced by the current. Besides, the insulators which were submitted to direct-current were found never to heat to any appreciable degree. This was not the case with alternating-current, and the effect may be explained in part by the absence of capacity effects with the former current.

The porcelain insulators which were put through the tests were provided with their ordinary iron fittings. Only a small number of insulators, and these of small size, were perforated. The spark took place in most cases at the exterior, between the binding of the line wire and the iron support. In this case it was easy to shift from direct-current to alternating in making the tests. The insulators which were perforated by the alternating-current were still able to resist very high voltages of direct-current in the laboratory. But when exposed to rain, the limiting voltages were naturally lowered, generally about one-half.

One fact to be noted is that there is scarcely any crackling noise with direct-current when the limiting tension of breakdown is approached; the reverse is true for alternating-current, which is often accompanied by considerable noise. In the same way brush discharges are hardly appreciable with direct-current, except when the explosive distance is nearly reached. Between two wires at 50 cm. (2 ins.) apart, nothing is observed, even at more than 60,000 volts direct-current. Sharp points, however, give a slight brush discharge. Relative to the sparking distance between the points, these brush discharges prepare for the passage of the spark. The latter then occurs in such an irregular manner that it was not possible to trace a curve which should be reasonably correct for the sparking distance between the points. The differences in these distances often reached from one to four.

It was not found possible to pierce the porcelain insulators used in telegraphy, even at 65,000 volts, as well as some others which are used in high-tension lines in Europe with a moderate voltage. In the present tests it is sufficient that the porcelain be well vitrified and homogeneous, and the thickness is of little importance. As long as we are within the sparking distance, this suffices, and as this distance is shorter for the direct-current, this explains why we must use direct-current voltages, which are much higher, in order to break down the insulation.

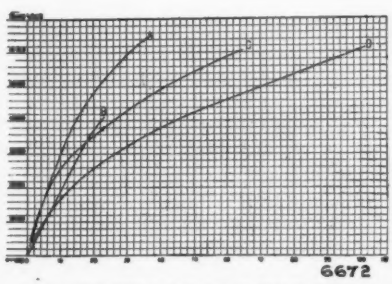


FIG. 2.—SPARKING DISTANCES, DIRECT-CURRENT.
A Two Spheres, *B* Point − and Plate +; *C* Plate +, Ball −, and *vice versâ*; *D* Point + and Plate −.

Glass is very difficult to pierce with direct-current. Ordinary white glass of 0·12 resists very well at 25,000 volts, and is only perforated when an oscillatory discharge is formed by means of a condenser. A sheet of window-glass will resist 60,000 volts direct-current, and no doubt still higher voltages.

What is of importance to note is that the present tests have fully confirmed the points which were only partially noted at the time of making the previous tests upon the transmission line from the hydraulic plant of St. Maurice to Lausanne (5,000 h.p., 22,000 volts direct-current). The latter tests already showed that the loss from insulation, even in time of fog, is practically zero at a voltage of 22,000 (0·02 watt per insulator of line), and it was to be foreseen that this voltage could be greatly increased before the losses by air and insulation would be appreciable. It seems certain at present that the limit voltage which we cannot exceed with the material which we now possess is much above 70,000 volts for direct-current, between the line and the ground. This fact makes the experiments which were carried on at Geneva extremely valuable, as it throws new light upon this important question. Thus the use of direct-current enables us to reach, industrially and very economically, distances which are more than double those which are attained with great difficulty by means of poly-phase-currents. That is to say, by the use of direct-current we can now reach a distance of 200 mls. with only 10 per-cent. loss, and 65 lbs. of copper per h.p. transmitted. As high as 600 mls. is covered with the same weight of copper and somewhat less than 30 per-cent. loss.

The results of the experiments made at Geneva may be summed up as follows:—

First series. Direct-current.—*Sparking Distance.* The results differ according to the nature of the electrodes between which the spark took place and the polarity of the electrodes. The four curves which are shown in Fig. 2 are obtained by the disposition of electrodes which give the most constant results. The spark between two points is quite variable, and it is impossible to trace a good curve. In the present curves, a point, sphere or plate is used as an electrode, as is specified below the curve.

A point to be remarked is the great influence of polarity in the case of electrodes which are formed by a point and a plate. While at 40,000 volts the negative point gives a sparking-distance of 22 mm., this distance is raised to 44 mm., or double, when the point is positive. The shortest distances are obtained between spheres (diameter, 20 mm), or 31 mm. at 60,000 volts, and the greatest distances between a + point and a plate,

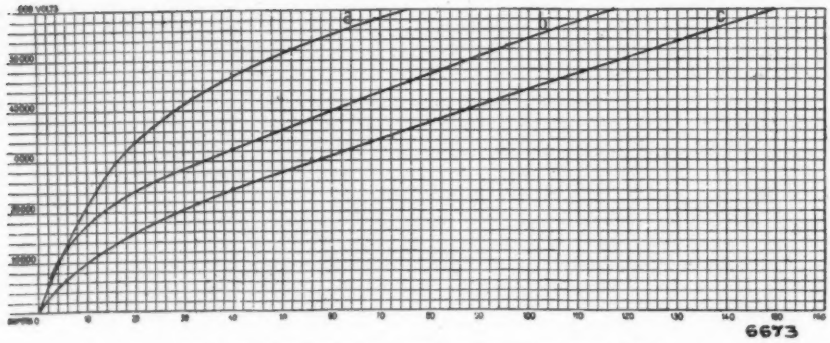


FIG. 3.—SPARKING DISTANCE, ALTERNATING-CURRENT, FIFTY CYCLES.
A Two Spheres: *B* Plate and Ball; *C* Plate and Point.

or 99 mm. at 60,000 volts, three times the value of the former case.

Second series. Alternating-current of 50 cycles.—The results are shown in the curve, Fig. 3. The same difference is observed between curves *a* and *c*. The former curve shows the spark passing between two spheres at a distance not above 74 mm. for 60,000 volts. It passes with the same voltage at 149 mm. between point and plate. The mean ratio of sparking-distance alternating-current and direct-current is respectively as follows in the different cases:

Two spheres at 30,000 volts, ratio 1·6; at 60,000 volts, ratio 2·5.
Plate and sphere at 30,000 volts, ratio 2·4; at 60,000 volts, ratio 1·85.
Point and plate at 30,000 volts, ratio 2·2; at 60,000 volts, ratio 1·51.

These ratios hold good even though the maximum tension of the alternating-current is but 1·255 times the mean tension, as the wave-form shows. This is explained partly by the fact that the sparking-distance increases more rapidly than the voltage. This ratio is much higher when we use the current from a central station, on account of the regular form of the electromotive-force curve which is due to the working of alternators in parallel or other reasons.

Third series. Tests of porcelain insulators of standard types, submitted in turn to alternating- and direct-current voltages, which are gradually increased until a short circuit occurs between the line wire and the iron bracket.—The latter is always connected with one pole. These tests are made in two distinct series, one in the laboratory, on dry and clean insulators; the second in the open air on insulators exposed to the weather during a certain time. Owing to a rainfall during an entire day, the tests could be made upon insulators which were quite wet. As will be noticed, the difference is considerable. The number of insulators tested together was too small to allow of making measurements of the energy expended with any precision, especially in the case of alternating-current. A slight tendency to heating was only noticed with the alternating-current at high voltage. The table below gives the results of the tests upon insulators:—

Mean of the Breakdown Voltages.		Ratio of A. C. and D. C.
Alternating Volts.	Direct Volts.	
15,000	24,000	1·60
21,400	31,000	1·59
27,000	40,000	1·48
34,700	45,300	1·35
31,160	40,800	1·31

Fourth series. Tests of different kinds of insulating material taken from the storeroom and used without any previous preparation.—The first was a sheet of glazed cardboard 5 mm. thick. With alternating-current, the results are as follows:—

Time of Application.	Voltage.	Remarks.
First test 1½ mins.	9,000	No effect.
,, 30 secs.	11,000	Spark passes through.
Second test 2 mins.	9,000	Strong brush discharge.
,, 15 secs. additional	9,000	Spark passes through.

The following results were secured when the same sheet was submitted to direct-current:—

Time of Application.	Voltage.	Remarks.
2 mins.	10,000	No effect.
2 ,,	15,000	,,
2 ,,	18,000	,,
2 ,,	20,000	,,
4 ,,	25,000	Spark passes through.

These results show that the cardboard, which is perforated twice by the alternating-current, after 2 mins. of applying 10,000 volts alternating-current, was able to resist for 12 mins. a mean tension of over 15,000 volts direct-current, and only breaks down after 4 mins.' application of 25,000 volts.

The second test was made upon a sheet of white marble 20 mms. thick (0·8 in.). With alternating-current the marble is perforated entirely after 75 secs.' application of 20,000 volts. A second trial gave 2 mins. and 15,000 volts. Using direct-current, the perforation is obtained only after 15 mins., from 10,000 to 45,000 volts, increasing the tension by 5,000 volts at a time during each two mins. As the piece was already weakened by the previous experiment with alternating-current, it showed a slight brush discharge at 10,000 volts, which increased up to the breaking-point of 45,000 volts.

All the substances which were tried gave analogous results. At the breaking-point, the voltages which are needed with direct-current are always double those of alternating-current. When capacity plays an important part, the difference is still greater. This shows that the difficulties in the industrial use of high-tension currents are much less with direct than with alternating-current, thus confirming what has already been seen in practice on several occasions. Thus the greater facility of insulation is noted not only for transmission lines, but also for all apparatus which is submitted to high tension, such as machines, motors and different appliances.

The problem of the transport of energy to several hundred miles has thus made a step in advance as a result of these experiments, now that the principal doubt has been settled. In the present tests it is not supposed that the industrial limit of voltage has been reached, however, and no doubt it can be raised considerably above 60,000 volts. It is hoped in the future that by constructing new machines it will be possible to make the tests with direct-current at 100,000 volts, for it is only necessary to connect four of the present 25,000-volt machines in series, and this does not seem to present any special difficulty.

BOOKS RECEIVED.

Small Destructors for Institutional and Trade Waste. By W. Francis Goodrich. (London: A. Constable & Co., Ltd.) 4*s.* net.

The Electric Furnace. By Henri Moissan. Translated by A. T. de Mouilpied, B.Sc., etc. (London: Ed. Arnold.) 10*s.* 6*d.* net.

Work and Wages.—I. Foreign Competition. By Brassey Chapman. (London: Longmans & Co.) 7*s.* 6*d.* net.

Electric Furnaces and their Industrial Applications. By J. Wright. (London: Archibald Constable & Co., Ltd.) 8*s.* 6*d.* net.

Smoke Prevention and Fuel Economy. By Wm. H. Booth, M.Am.Soc.C.E., and John B. C. Kershaw, F.I.C. (London: Arch. Constable & Co., Ltd.) 6*s.* net.

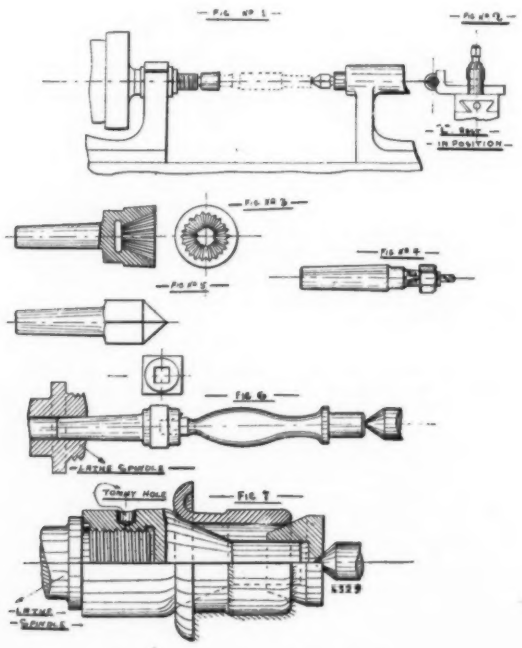
Steam and Steam Engines, including Turbines and Boilers. By Prof. Jamieson. Fourteenth Edition. (London: Chas. Griffin & Co., Ltd.) 10*s.* 6*d.* net.

The Progress of Warship Engineering in 1903-4. By Chas. de Grave Sells, M.Inst.C.E. (London: Sampson Low, Marston & Co., Ltd.)

WORKSHOP PRACTICE NOTES.

Handy Lathe Tools and Appliances.

SOME time ago we had a very great number of small shafts and spindles to machine, they would weigh from 1 to 4 lbs. each. The one shown dotted in Fig. 1 was a running order, about 8 ins. long and 1¼ in. diam. on largest part. At the commencement of the week, a man would take enough out of the stores to last until the following week; and as they required the centres leaving in the ends, it will be seen that shortening and recentring occupied a large percentage of total time for turning. They were handled at a price I have never seen equalled, by the following method and appliances. The live centre of the lathe was replaced by the chuck (Fig. 1) shown in detail in Fig. 3, and the dead centre replaced by square centre, Fig. 5, the L rest placed in tool post as at Fig. 2. The lathe was started, and kept running until the whole of the spindles were centred. The spindle end is lightly held in the chuck by hand, and the square centre gently forced against the other end. The L rest is then fed against the spindle until it runs true and in that position the centre is pressed home. The centre is then slacked back, and the spindle is caught in the hand and another inserted—the lathe continuing to run until all are centred. The square centre is changed for a "half-centre," and a special shortening tool is used, a kind of hybrid—



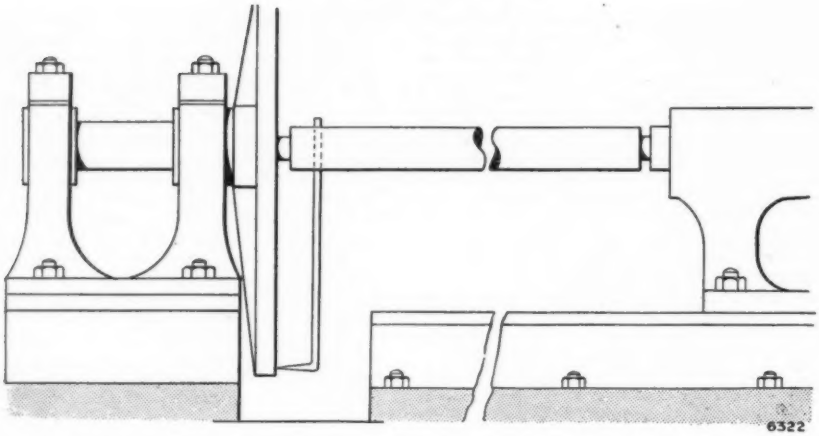
HANDY LATHE TOOLS AND APPLIANCES.

between a "knife" tool and a "roughing" tool—with a finer cutting-edge than the former, and the strength and rigidity of the latter. The chuck is still retained for driving, and all the spindles are shortened. In view of the shoulders and ends having to conform to an overall length gauge, it will be seen what an advantage it is to be able to try the gauge without removing a carrier, or even stopping the lathe. When all are shortened, the centres are ground off, and they are then re-centred as before. The drill shown in Fig. 4 now takes the place of the square centre, and all centre bottoms are deepened. The chuck is used on work up to 2 ins. diam. and 3 ft. 6 ins. long. We had several centring machines, but the outfit shown in Figs. 1 and 2 more than held their own on fairly heavy work, and on the former class of work there is no comparison in cost. Further, the work is always true at the ends, no matter how it may be bent. Also the work revolving under the eye shows any serious error in forging, and allows the forging to be humoured and centre drawn to suit. Another handy chuck is that shown in Fig. 6, and many purposes for which it is suitable will suggest themselves. It is shown in this case operating on malleable iron handles about 5 ins. long and $1\frac{1}{4}$ in. diam. They have a taper end of square section cast on, which fits a similar taper square-hole in chuck; the faceplate is removed and the handles are all roughed out on body, and the end finished for riveting completely. The saddle is then run on the back side of loose headstock. A hand-tooling rest is now put up and the body of handle is finished by hand tool. And finally the square projection is nicked ready to snap off. The absence of faceplate and carrier is a great convenience. I think the system of having projections on small forgings and castings can be made a great saving on many jobs if thoughtfully carried out. Another saving of time is effected by the mandrel shown at Fig. 7. It held the malleable iron ferrules used at the fire-box end of marine boiler tubes. They were about $2\frac{1}{4}$ ins. or $2\frac{1}{2}$ ins. diam. and 3 ins. long, turned where shaded. They were rough castings, so light that they were often distorted. The ferrule is shown in position at Fig. 6. With this device the cost of production was reduced about 70 per cent.

[In this case, the small cone forced up by dead centre might be made to revolve on a spindle taking the place of the dead centre.—Ed.]

Lining up a Large Lathe.

The following description of the way in which the spindle of a 16-ft. facing lathe was trued up may be of interest, as the lining up of a lathe of this size is not an every-day occurrence. The head of this lathe was entirely separate from the shears, a large gap being between the ends of the shears and the faceplate, the depth of the gap being about 3 ft. from the top of the shears. For some reason the back end of the headstock had sunk down and thrown the faceplate out of truth with the centres, thus making it impossible to turn out a good job on the lathe without having the rests on the saddle moved round off the square of the shears. One of the supporting columns for the roof, which also carried the overhead crane runways, was a short distance away from the end of the lathe, and this was the only thing that could be thought of that would have any effect on the foundation of the lathe. Whatever it was, there was the spindle out of line and it would have to be trued up. The first thing done was to turn up the centre perfectly true; this being done, the back centre was then tried and found to be in its right position in the centre of the shears. A tool was then placed in the rest of the lathe and the faceplate turned round to see whether there was any twist in it; finding this all right we were ready to square it up by means of a bar between the centres of the lathe, and having an index finger attached to it which indicated at the outside edge of the faceplate when turned round by the bar. A long stiff boring bar was got, having good centres in it and a square hole through it near one of the ends, the length of this bar being about three times that of the index finger, so that any slight inaccuracy in the centres would be reduced rather than multiplied; this left the back centre about midway on the shears. A length of square iron was then got to fit the hole in the bar, having one of its ends drawn down to a point and bent at right angles to the rod, the length of the bend being such that when placed in position in the bar the point would be about $\frac{1}{4}$ in. clear of the faceplate. The rod being cut to the length and set in position, the pointer was about $\frac{1}{2}$ in. from the outside edge of the faceplate, the rod being held in the bar by means of wedges. On tightening up the centres so that the bar could be easily turned, but without any play, it was found that the pointer touched at the bottom and was $\frac{1}{2}$ in. clear at the top; this showed that the back end of the spindle required to be raised. The pointer was then tried at the sides of the faceplate, and the same measurement was got at each side, showing that no movement had taken place in this direction. To make sure, however, that there was no inaccuracy in the centres



LINING UP A LARGE LATHE.

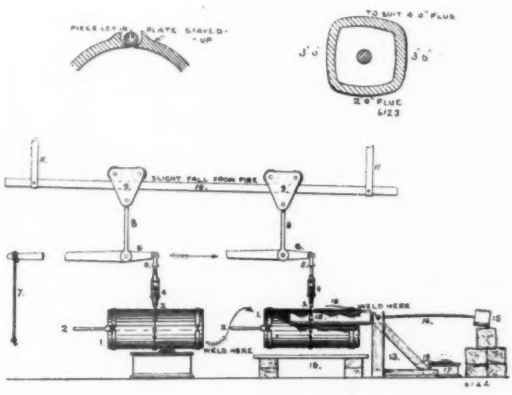
or the spindle the faceplate was given a half-turn, and the pointer tried round again, when practically the same results were got. The bar was then tried to see if it was level with the shears, a straight-edge being placed across them and the distance from this to the bottom of the bar measured by a micrometer gauge; one measurement being taken at the centre and the other at the end of the shears, care being taken that the two places on the bar were the same diameter, and the bar given a half-turn to allow for any slight bend that might be in it. This showed that the centres were practically parallel with the shears. The question now was, how best to get the spindle level, whether to put a liner under the back bush, or reduce the bottom brass of the front bush; it was decided not to touch either of the bushes, as to do so a lot of gearing would have to be disconnected, and the spindle and faceplate lifted out, and as this would take some time it was decided to lift the head bodily and pack it up, especially when it was found that it had been packed up in the same manner before, the head proper being bolted on to a sort of bedplate, the packing being between this and the head. Two powerful screwjacks were got, and, after the holding-down bolts were slacked, the head was raised about $\frac{1}{8}$ in. at the back. The pointer was then tried round the faceplate, and it was found to be true. New packing pieces were then fitted in, these being simply iron plates of the proper thickness, and, as the head had a bearing all its length, and was resting on the front end, it was necessary to step down the packing, this being done by using thinner plates and levelling up with tin. Of course, it would have been better to have fitted in a wooden pattern and had an iron packing piece made the same size as it, but there was not time for this. After it had been packed up it (the head) was raised about $\frac{1}{4}$ in. higher and the top of the packing pieces covered with thin red lead; this was to fill up any spaces and to hold the packing together. The jacks were now slacked back and the bolts screwed up, and the faceplate being tried and found correct this finished the job. The lathe has since done a lot of heavy work, on which there was a lot of uneven cutting, thus causing a good deal of vibration on the head, but the packing shows no tendency to slack and is as firm as when first put in. W. B.

Furnace-Tube Welding Equipment.

In the colonies, such as the Commonwealth of Australia, where the artisan, and especially the engineer, is so far removed from the old country, where he could be within reach of the specialists in furnace-tube manufacture, it is often a clause of the specification of the boilers that completion and delivery must be made within a certain period. Hence, being so far away—and variation in sizes required does not warrant keeping large stock—the boilermaker has to resort to the manufacture of the tubes himself, and to plan a gear which will enable him to weld his tube with the necessary alacrity often

taxes his ingenuity; and once he gets his own arrangements he never leaves them. In my works managing experience I have seen many such gears, but I find the application herewith described, which I have lately installed, to be the most successful in being able to transfer the tube from the fire to the block in such time as to get most advantage of the welding heat. Neglecting the operations of making the plate with the necessary conditions for welding, viz., shearing, staving up, and rolling, and placing on clamps, and also placing a rivet in each end between the joint, to keep the plates from closing in during the welding operation, we will imagine the tube (1) with the horns (2) ready, by the fire, to be placed in a position to be picked up by the lever and gear here described. Nos. 3 to 5 are the collar-chain, wheel, and swivel to be attached to the lever (6) of such length and centres that, with the rope (7), a youth is able to handle the weight of the tube with ease. The lever is hung from the roof by means of the link (8) and trolley (9), which runs on a rail (10), which has a slight incline out of the fire for easy running; which same rail is hung from the roof by means of suitable attachments (11) as the building warrants. The anvil block (12) is made to different radii, as shown, supported on a fixed base (13), but weighted and balanced, and loaded solid, by means of the bar (14), and weights (15). The staging (16) is sufficiently high as to give the men striking sufficient power with their hammers. No. 17 is the fire where the welding piece (18), to be let in, is heated, and is sufficiently near to let the heater get from the fire on to the tube in as short a space of time as possible. No. 19 is an ordinary open blacksmith's fire for heating the tube with, tuyère and black cock complete. The *modus operandi* needs little explanation, and is as follows:—When the boilermaker is satisfied that he has the right heat on his tube, and the piece heater is ready, he gives the word. The youth on the rope (7) weighs his lever down slightly, raising the tube out of the fire as another hand puts off the blast; at the same time another youth at the horns steadies the tube, pushing forward and stepping over the fire, and directing the tube on to the anvil. Immediately the nose of the tube is over the anvil—and before the man at 7 lets his lever up—the man at the horns spins the tube round in the collar chain, bringing the weld up on to the top of the anvil ready to receive the piece (18), which is now arrived, and being placed in position, the weld is complete. By this arrangement it is possible for a boilermaker, two helpers (including the heater), and two youths to weld a tube of any size up to 4 ft. diameter, 7 or 8 ft. long, and weighing upwards of 10 cwts. at the rate of about 5 ins. per 6 to 10 minutes.

D. G.



FURNACE-TUBE WELDING EQUIPMENT.

CATALOGUES AND TRADE PUBLICATIONS.

Acetylene Generating Plant.

Acetylene Corporation of Great Britain, Ltd., 49, Victoria Street, Westminster.—Fifth edition of their catalogue of acetylene plant and accessories, with some examples of installations as applied to the lighting of churches, schools, hotels, shipyards, country houses, etc.

Printing Machinery.

H. O. Strong & Co., St. Paul's, Bristol.—Catalogue of machines and appliances for letterpress and lithographic printing and the allied trades.

Prime Movers.

J. & H. McLaren, Midland Engine Works, Leeds.—Illustrated list of leading types of electric generating engines as installed in some of the leading power stations, such as Leeds, Sheffield, Huddersfield, etc. Messrs. McLaren were pioneers in the manufacture of triple-expansion engines for generating electricity, having introduced them in 1891. The piston-valve is not in favour at the Midland Engine Works, a special form of balanced slide-valve being fitted on all their engines. This, combined with a patent automatic expansion-gear and governors, secures a very satisfactory steam distribution, as is evinced by several diagrams reproduced in the catalogue.

Traction Engines and their Uses is the title of an interesting and well-printed *brochure* now being issued by the same firm. It is from the pen of Mr. John McLaren, M.Inst.C.E., and deals with the construction of self-propelling engines for haulage and thrashing purposes. The process of manufacture described is that employed at Messrs. McLaren's works.

Dynamos and Motors.

Mather & Platt, Ltd., Salford Iron Works, Manchester.—The third edition of the multipolar dynamo catalogue.

Crompton & Co., Ltd., Salisbury House, London Wall, E.C.—Well-illustrated catalogue of continuous current motors with special reference to the several improvements lately made in the design of these machines, which are manufactured in 14 standard sizes, the normal outputs ranging from 2 to 125 b.h.p., and are wound for 110, 220, 440, and 500 voltages. These motors can be supplied in four different types, "protected," "semi-enclosed," "dust proof," and "totally enclosed."

Boilers.

The Hardie-Thompson Company, 110, Cannon Street, London, E.C.—Pamphlet No. 1, describing and illustrating the Hardie-Thompson boiler. This is of the water-tube type, the most important feature of which is in connection with the circulation of the water in the tubes. By the system employed the circulation in each tube is entirely independent of the circulation in the remainder of the tubes; in fact, any tube can be withdrawn from the boiler and its hole in the steam drum plugged without interfering with the circulation. By the simplicity of its parts—there are no headers—transportation and erection are facilitated. The latter is not a difficult operation, and can, say the makers, be carried out with unskilled assistance.

The Rust Boiler Company, Pittsburg, Philadelphia.—Well-illustrated descriptive pamphlet of this company's water-tube boiler. The patent tube sheet, used in the construction of the drums, is the most characteristic feature of this generator, as by its use bent tubes or stayed surfaces are not necessary.

Holden & Brooke, Ltd., West Gorton, Manchester.—List No. 69, describing Brooke's patent automatic boiler-feed regulator. This apparatus is fitted entirely outside the boiler, for controlling the height of feed and maintaining a steady water level in steam boilers.

Measuring Machines.

The Newall Engineering Co., Ltd., Atherton's Quay, Warrington.—A well-printed catalogue of this firm's specialties, notably measuring machines, end rods, limit gauges, reference bars, surface places, etc. Particular mention must be made of a new pattern of internal micrometer, which differs from the usual style of instrument in that it has three measuring points, an advantage which will appeal to all who have occasion to accurately measure internal diameters. The measuring points are hardened and ground on the outside ends to spherical form, the points being operated by a micrometer spindle contained in the body. As the spindle moves forward, so the three legs are thrust outwards until they come in contact with the sides of the hole to be measured. By its use the makers state that six different men will measure the size of a hole without showing a difference of ·25 of 1,000 at the most.

Pumps.

W. H. Bailey & Co., Ltd., Albion Works, Salford, Manchester.—Pamphlet dealing with Bailey's "Davidson" patent steam pumps for boiler feeding, circulating, etc. This pump is a direct double-acting pump with a single steam end, simple, compound, or triple expansion.